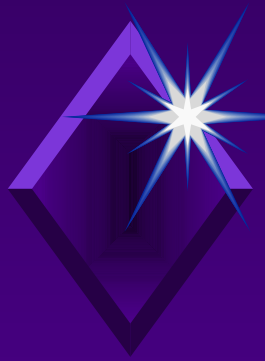


TROPICAL CYCLONES



TROPICAL CYCLONES OVERVIEW

- ◆ **CYCLONE OVERVIEW**
- ◆ **DEFINITIONS**
- ◆ **HURRICANE CATEGORIES**
- ◆ **CONDITIONS OF READINESS**
- ◆ **TROPICAL CYCLONE FORMATION**



TROPICAL CYCLONES OVERVIEW (con't)

- ◆ **TROPICAL CYCLONE CHARACTERISTICS**
- ◆ **AREAS OF POTENTIAL DEVELOPMENT**
- ◆ **STORM TRACKS**
- ◆ **SORTIE/NO SORTIE DECISIONS**
- ◆ **OPTIMUM TRACK SHIP ROUTING**



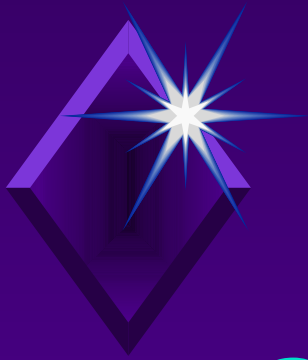
A. SHIPS AT SEA

- ◆ **MONITORING THE STORM**
- ◆ **WHAT TO DO UPON RECEIPT OF TROPICAL CYCLONE WARNINGS**
- ◆ **TROPICAL CYCLONE EVASION**



B. SHIPS IN PORT AND SHORE COMMANDS

- ◆ **MONITORING THE STORM**
- ◆ **TROPICAL CYCLONE WARNINGS**
- ◆ **WHAT TO DO UPON RECEIPT OF TROPICAL CYCLONE WARNINGS**
- ◆ **SORTIE TO SEA**
- ◆ **SHORE SITE PREPS**



*C. TROPICAL CYCLONE
DISSIPATION*

D. OTSR INFORMATION

E. QUESTIONS



MUST HAVE REFERENCES

- ★ **OPNAVINST 3140.24E** (Warnings and Conditions of Readiness Concerning Hazardous or Destructive Weather Phenomena)
- ★ **CINCLANTFLT OPORD 2000 (ANNEX H)** (Meteorology and Oceanographic Services Inst: Heavy Weather Doctrine)
- ★ **NAVOCEANCOMINST 3140.1 (k)** (U.S. Navy Met/Ocean Systems Support Manual)
- ★ **LOCAL 3140/3141 BASE INSTRUCTIONS** (Destructive Weather Plan)



MUST HAVE REFERENCES

*** HURRICANE HAVENS HANDBOOK FOR
THE**

**NORTH ATLANTIC
(NAVENVPREDRSCHFAC
Technical Report)**

*** HEAVY WEATHER GUIDE**

*** NATIONAL HURRICANE OPERATIONS
PLAN**

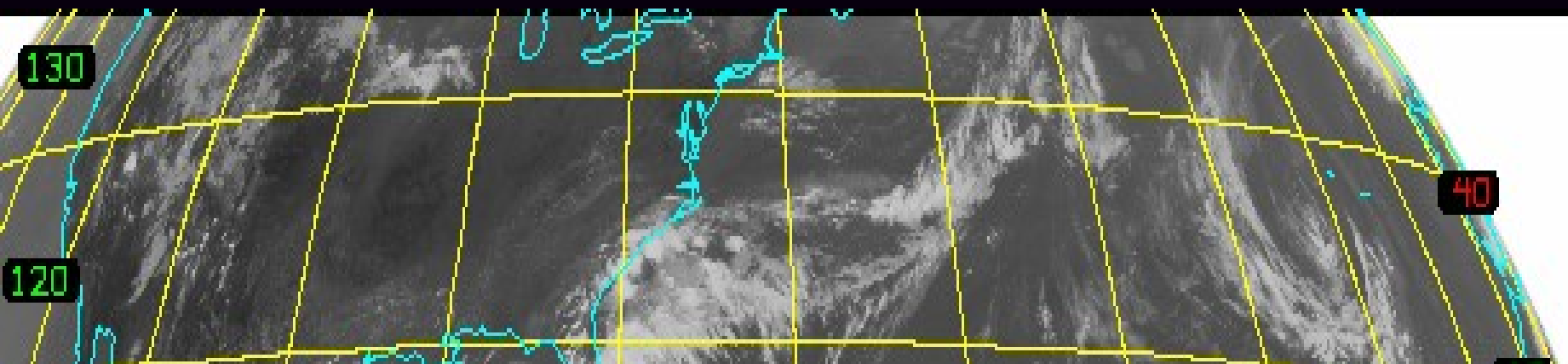
**(NHOP). (Available from the Tropical
Prediction**



OTHER REFERENCES

- ◆ **TROPICAL CYCLONE FORECASTERS REFERENCE GUIDE**
- ◆ **AEROGRAPHERS MATE 1&C**
- ◆ **HURRICANE FORECASTING (GUIDE 3): U.S. DEPT OF COMMERCE**
- ◆ **AMERICAN PRACTICAL NAVIGATOR (Bowditch)** -detailed description of the cloud and barometric tendency sequence during cyclone approach

TROPICAL CYCLONE OVERVIEW





DEFINITIONS

Tropical Cyclone: A warm core , non-frontal, synoptic scale system with *cyclonically rotating winds* characterized by a rapid decrease in pressure and increase in winds toward the center of the storm. Cyclones develop over tropical or subtropical waters and have a definite *organized circulation*.

Tropical Depression(TD): A tropical cyclone with wind speeds to *33 knots*. Identified by the letters “TD” and suffixed by a number (TD-01: the first tropical depression of the current calendar year.....TD-02, the second, etc...)



DEFINITIONS

Tropical Storm (TS): A tropical cyclone with wind speeds *34 to 63 knots*. Identified by noun names, alternating between male and female in alphabetical order. (TS Arthur, Bertha...). First tropical cyclone this year will be named Tropical Storm ANA (#4 DANNY, etc...)



DEFINITIONS (cont)

Hurricane: A tropical cyclone with wind speeds *greater than 63 knots*. Identified by the same noun carried when it developed into a TS.

◆ **Most damaging aspects of a hurricane are:**

INPORT:

1) Storm Surge

2) Tornado & Severe TSTMS

AT SEA:

1) High Seas

2) Winds

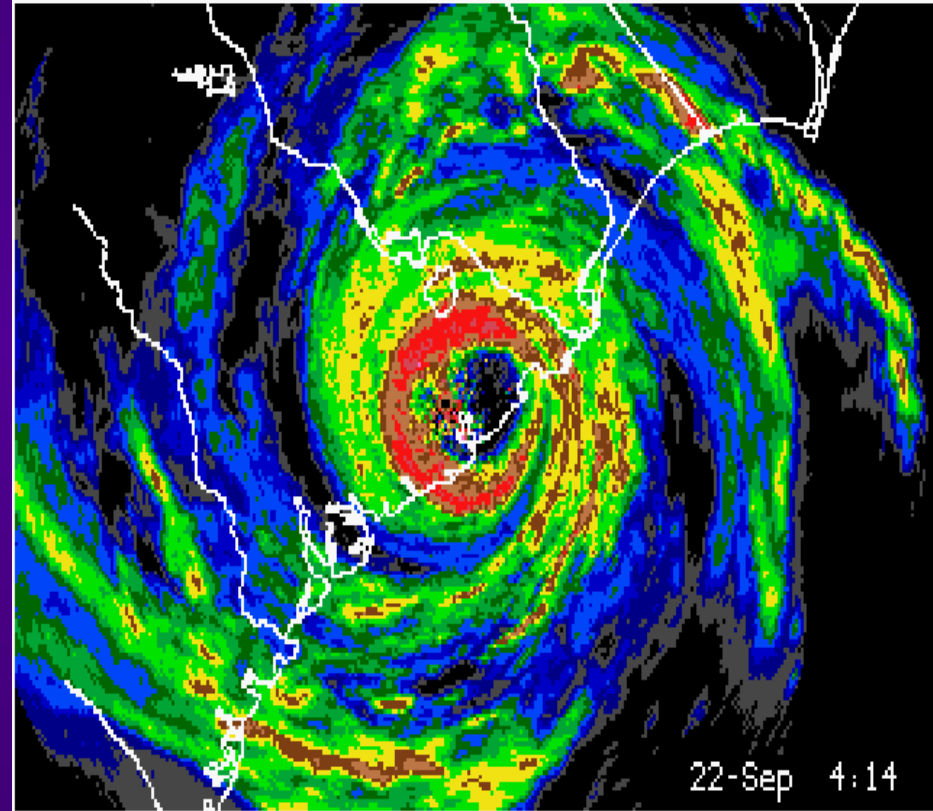


DEFINITIONS (cont)

- ◆ **Western North Pacific: Typhoon**
- ◆ **Australia: Willy willy**
- ◆ **Philippines: Baguio**
- ◆ **India: Cyclone**

DEFINITIONS (cont)

Storm Surge: *Abnormal rise of the sea in advance/with the cyclone formed by the cyclone's onshore winds to the right of the cyclone center and low pressure near the cyclone's center.*
"WALL OF WATER"





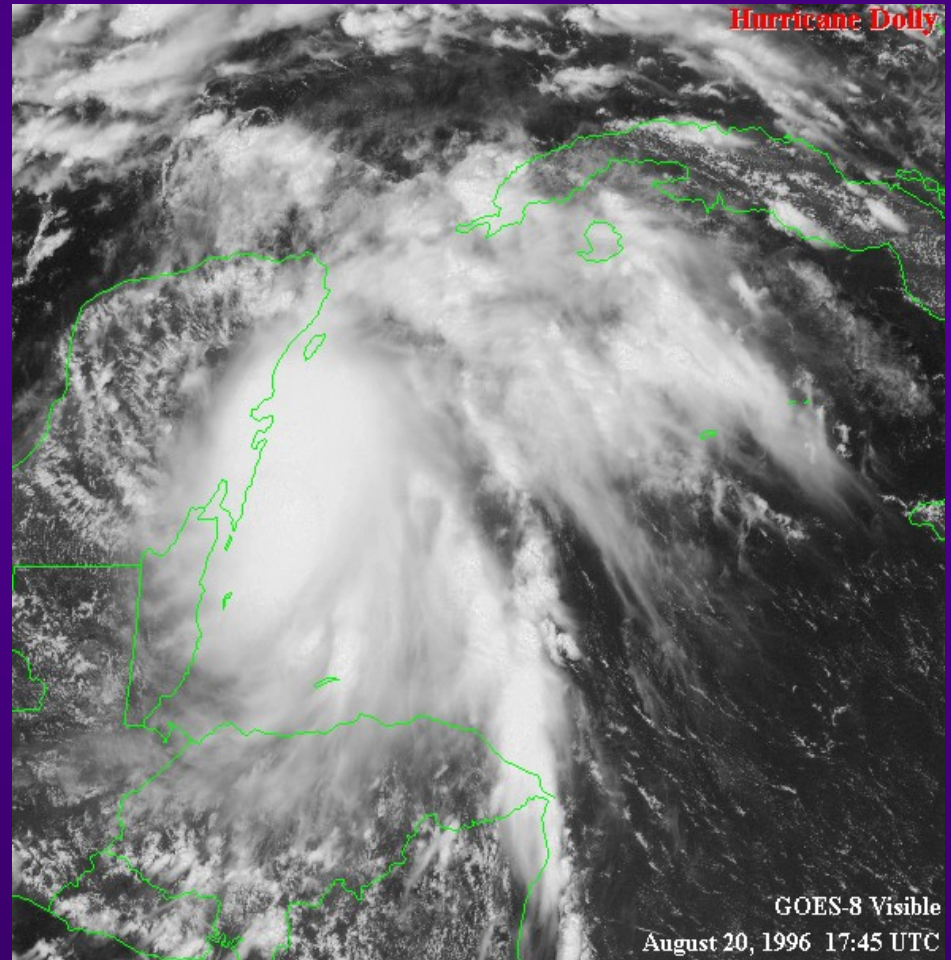
DEFINITIONS (cont)

Saffir-Simpson Scale: Predicts amount of storm surge. Severity dependent on storm's angle of approach to the coast and bathymetric slope of the coastline; most dangerous when coincident with high tides.



HURRICANE CATEGORIES

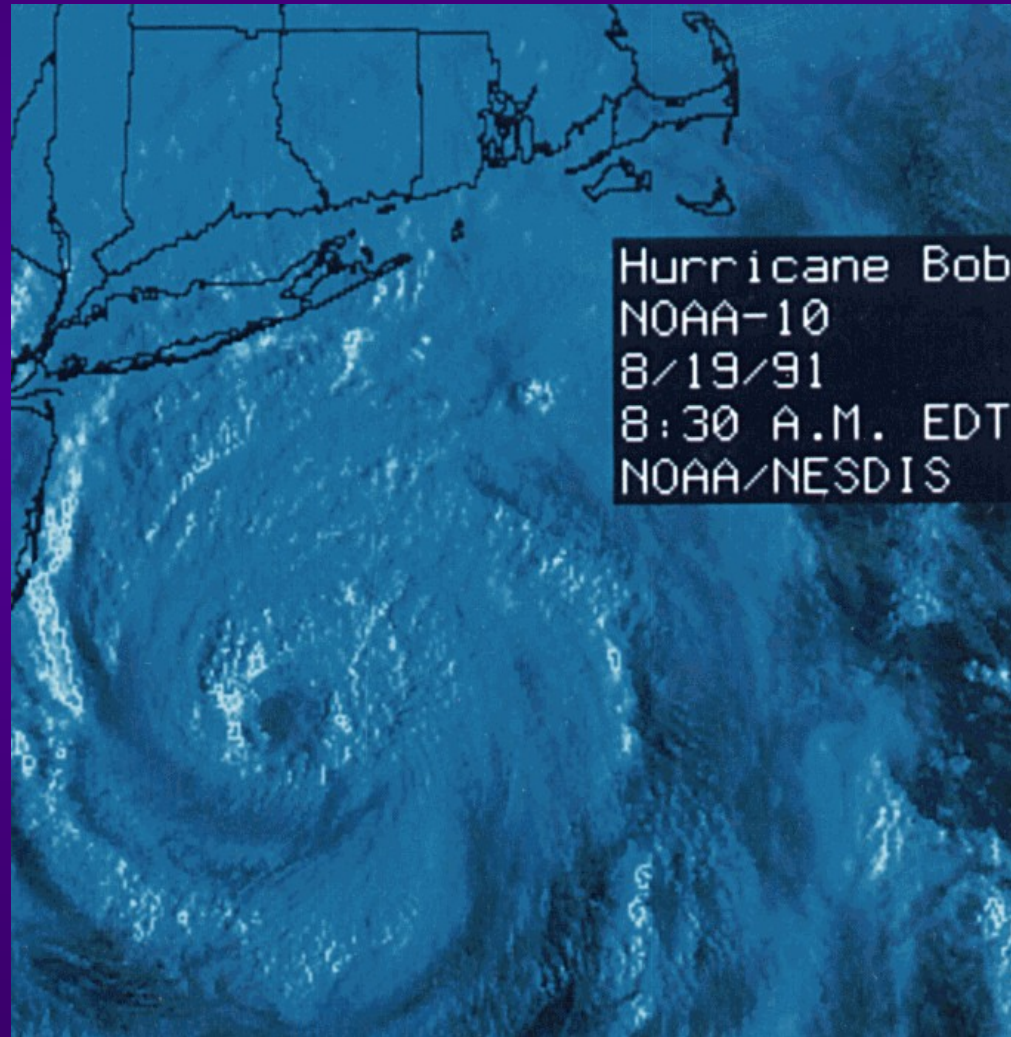
Category 1
(Minimal) - Winds 64 to 82 knots, storm surge 4 to 5 ft above normal. No real damage to building Structures. Low lying coastal areas flooded, minor damage to piers.
(DOLLY 1996)





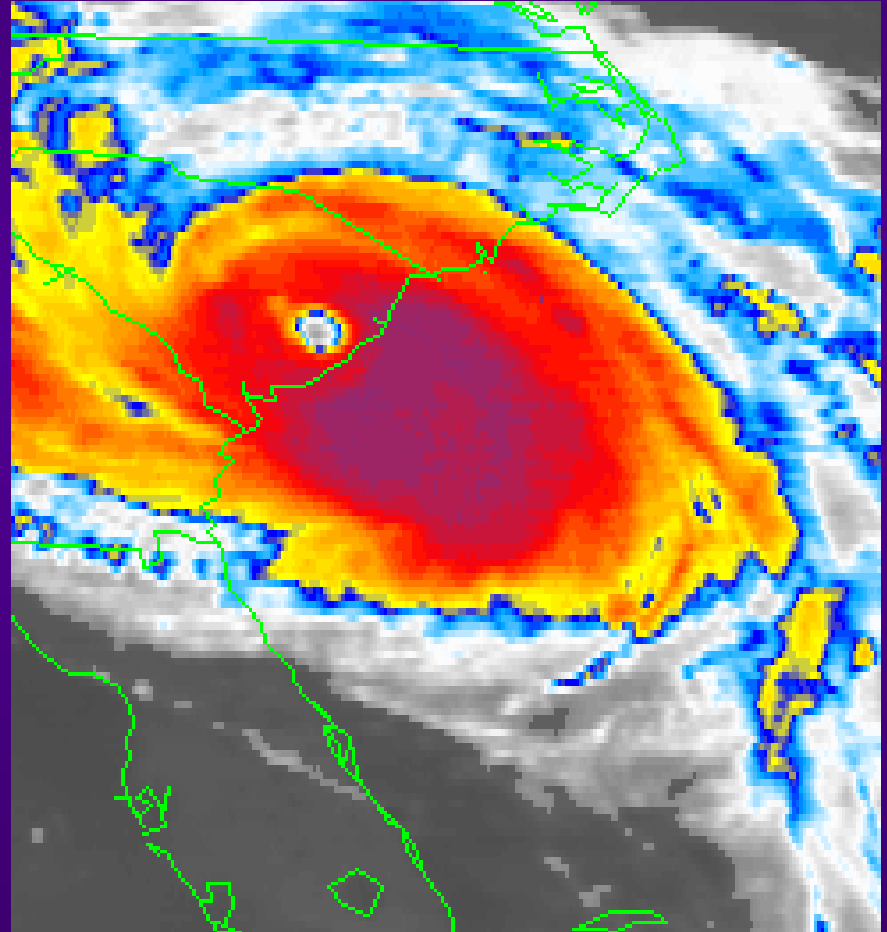
HURRICANE CATEGORIES

**Category 2
(Moderate)** - Winds 83 to 95 knots, storm surge 6 to 8 ft above normal. Minor damage to structures, poorly constructed buildings major damage. Coastal and low lying escape routes flooded over, considerable pier damage



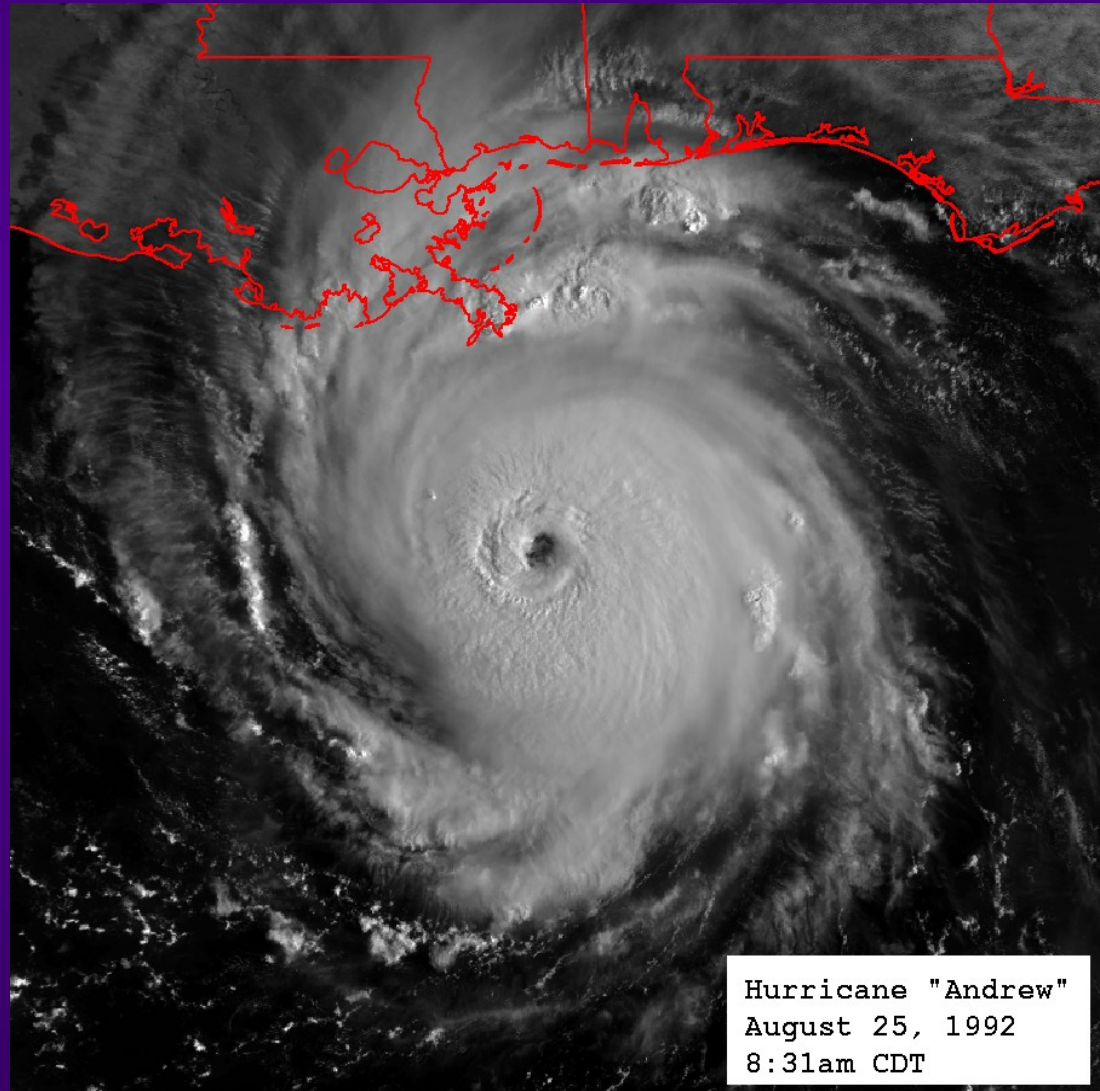
HURRICANE CATEGORIES

Category 3
(Extensive) - Winds
96 to 113 knots,
storm surge 9 to 12
ft above normal.
Major damage to
structures , poorly
constructed
buildings
destroyed. Serious
flooding along the
coast, extensive
flooding may
extend inland 8
miles.
(HUGO 1992)



HURRICANE CATEGORIES

Category 4
(Extreme) - Winds
114 to 135 knots,
storm surge 13 to
18 ft above normal.
Extensive roofing
and window
damage, complete
destruction of
mobile homes.
Areas above 10 ft
flooded inland up to
6 miles, major
erosion of beaches,
massive evacuation
of coastal areas.
(ANDREW 1992)

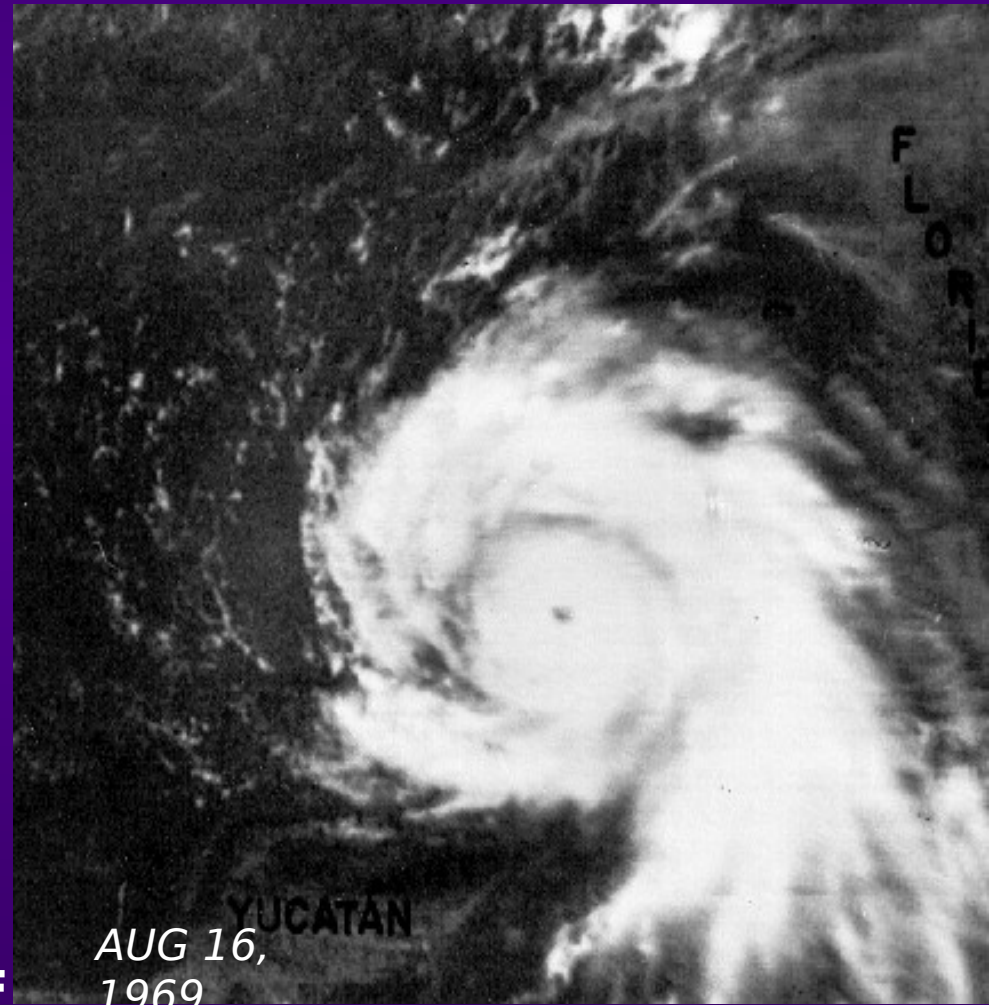


Hurricane "Andrew"
August 25, 1992
8:31am CDT



HURRICANE CATEGORIES

**Category 5
(Catastrophic)** - Winds above 135 knots, storm surge greater than 18ft above normal. Complete failure of roof structures and very severe window and door damage, some complete buildings fail. Major damage to structures lower than 15 ft above sea level, massive evacuations of residential units within

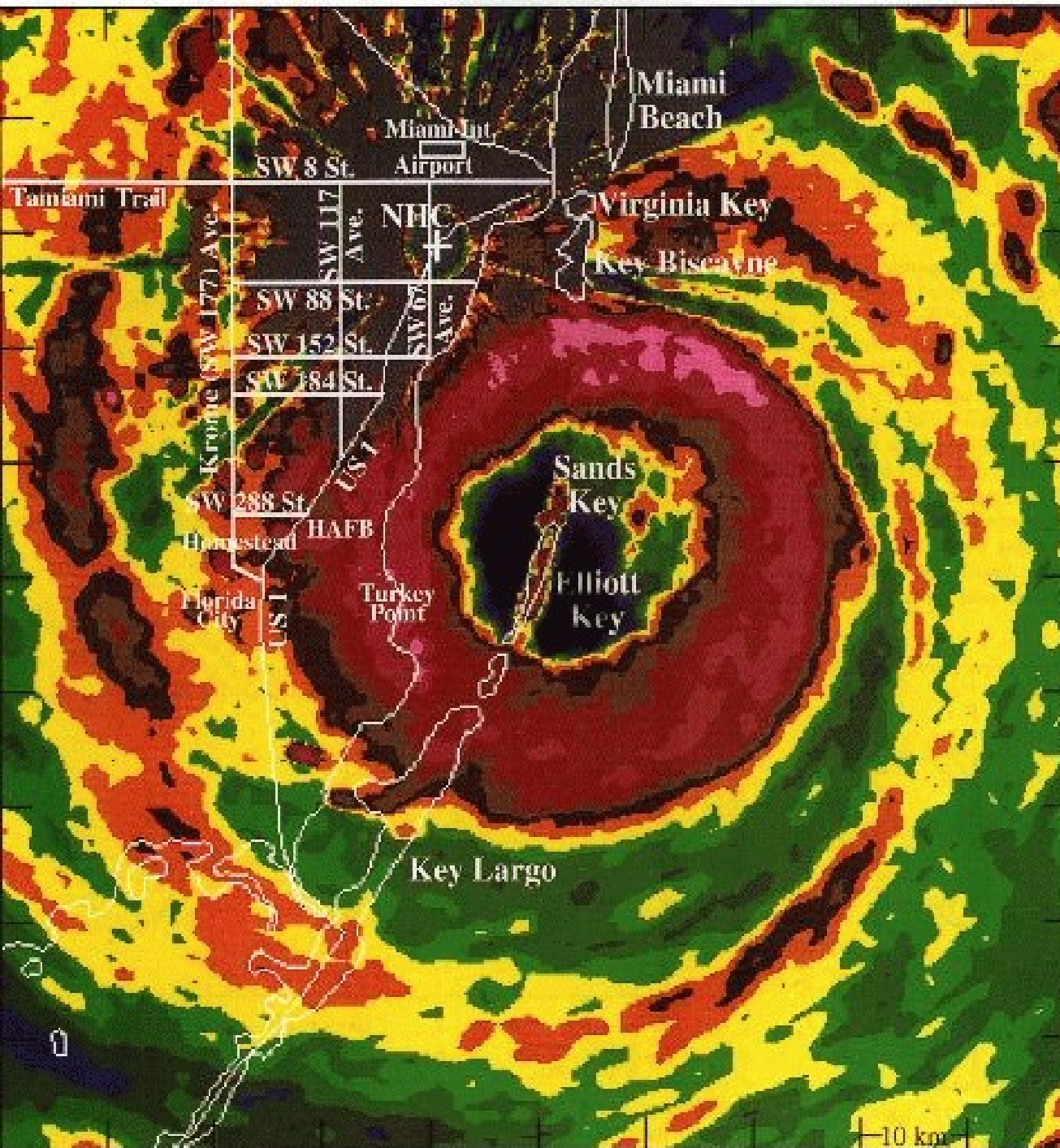


HURRICANE ANDREW

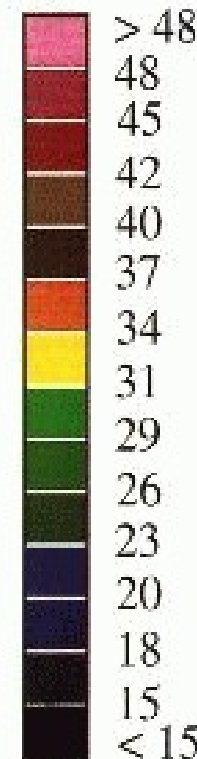
NWS MIAMI RADAR

August 24, 1992

08:35 UTC 04:35 EDT



dBZ



Hurricane
Research
Division

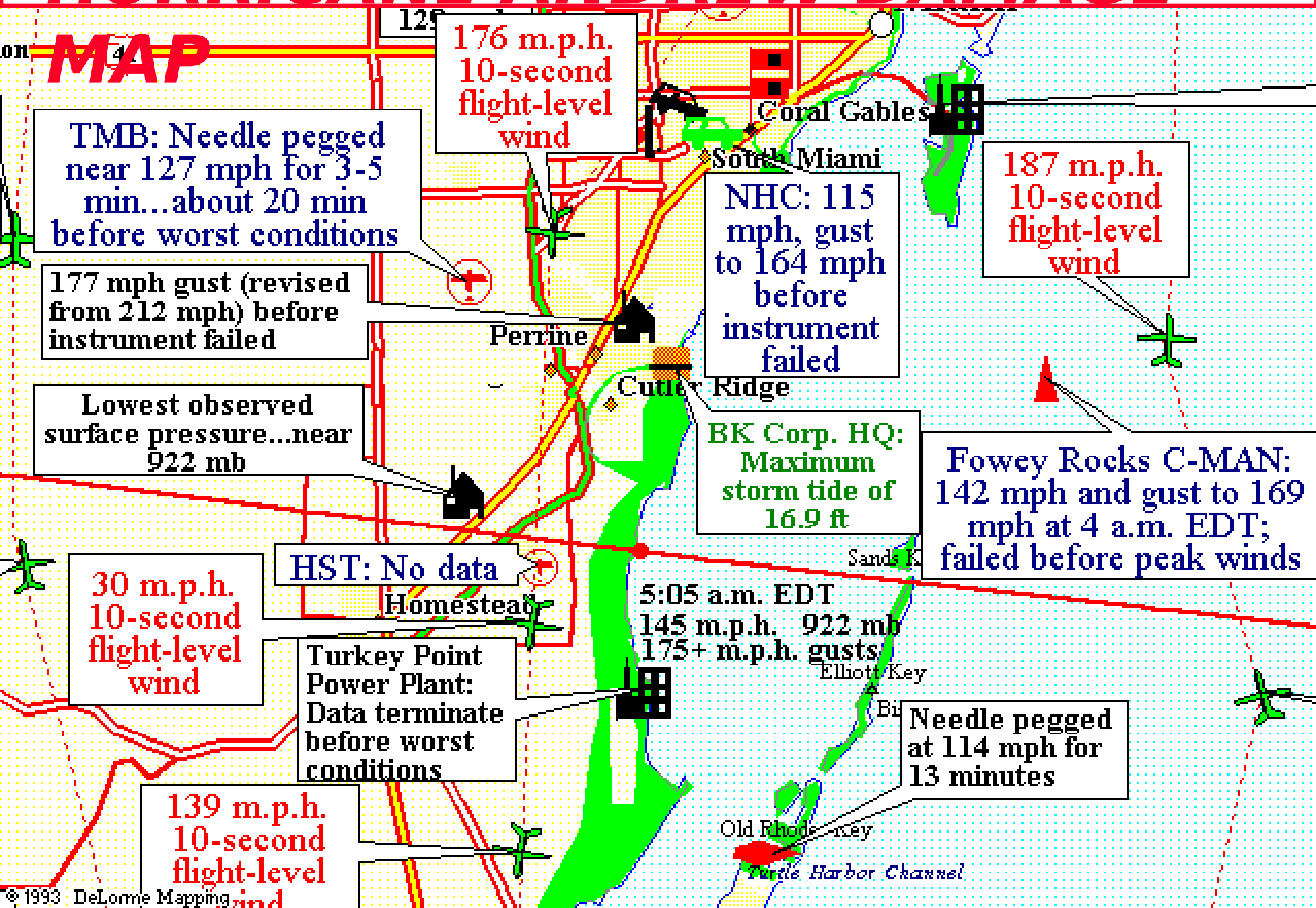


NOAA/AOML
Miami, FL

Domain: 100 x 100 km

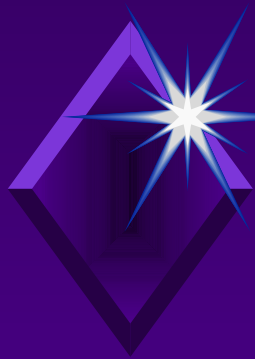
HURRICANE ANDREW DAMAGE

MAP









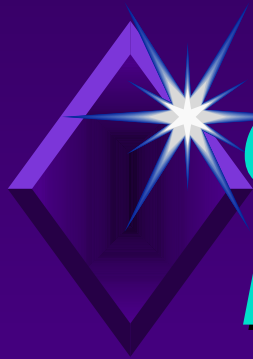
TROPICAL CYCLONE CONDITIONS OF READINESS

CONDITION V - Destructive force winds (35 kts or as specified *) are possible within 96 hours.

CONDITION IV - Destructive force winds are possible within 72 hours.

CONDITION IVA - Destructive force winds are possible within 72 hours. (Cuba and Puerto Rico maintain this condition throughout the season)

*** DESTRUCTIVE FORCE WINDS ARE DELINEATED BY LOCAL 3140 INSTRUCTION**



CONDITIONS OF READINESS

CONDITION III - Destructive force winds are possible within 48 hours.

CONDITION II - Destructive force winds are *anticipated* within 24 hours.

CONDITION I - Destructive force winds are *anticipated* within 12 hours.

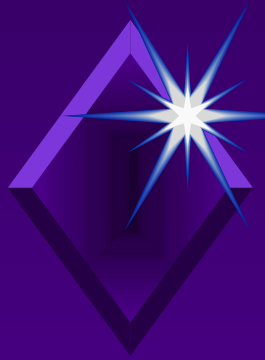


SORTIE CONDITIONS OF READINESS

CONDITION C - Prepare to sortie within 36 to 48 hours to avoid heavy weather. Anticipated sortie commencement time will be included in the message setting sortie C. Depending on predicted storm track, sortie C may be set with Tropical Cyclone Condition

CONDITION B - Sortie expected within 24 hours to avoid heavy weather.

CONDITION A - Commence sortie to avoid heavy weather.

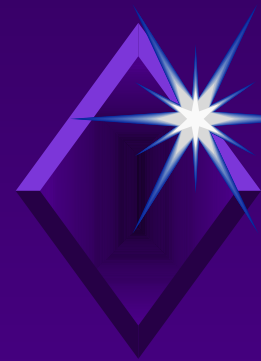


TROPICAL CYCLONE FORMATION

Season: Atlantic - 01 June through 30
November

Eastern Pacific - 15 May through 30 Nov

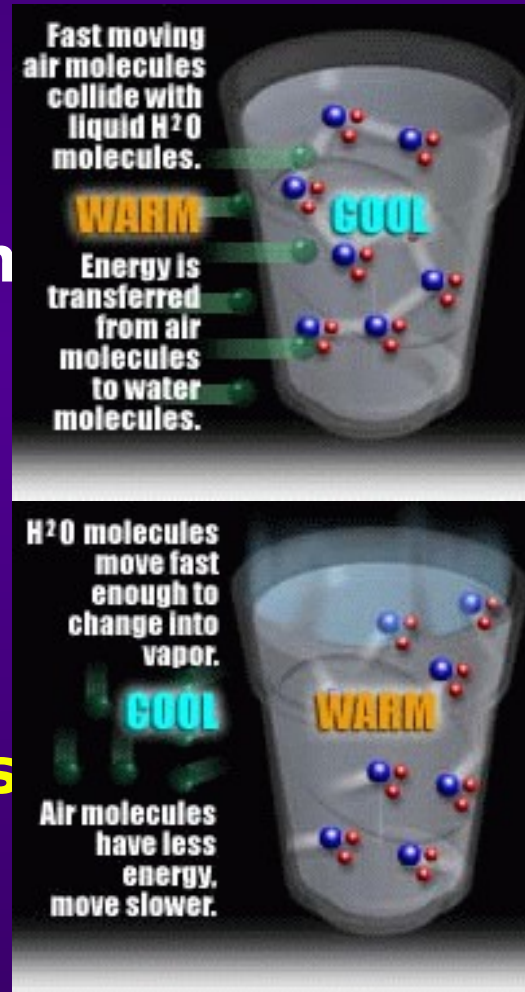
Western Pacific - year round



TROPICAL CYCLONE FORMATION

B. Conditions Required for Formation

- ◆ **SST > 78 F** (tropical waters, uniform over vast area - symmetrical)
- ◆ **low level winds converging** (8-20N, ITCZ)
- ◆ organized **convection** (disturbance) - latent heat
- ◆ disturbance **moving less than 13 kts** (easterly waves, etc...)
- ◆ **Upper Level outflow** (divergence)



**Warm, humid
air spirals in
toward eye,
gaining speed
toward center.**

**Winds weaken
with height and
air spirals outward
clockwise at
high altitudes.**

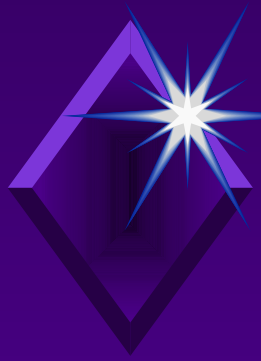


**Air sinking
inside eye
inhibits clouds
and rain.**

**Surface winds
spiral counter
clockwise
toward eye.**

**Maximum wind
found in eye
wall at surface.**





TROPICAL CYCLONE: Stages of Development

**1. Tropical Easterly Wave
Tropical Storm**



3.



**2. Tropical Depression
Hurricane**



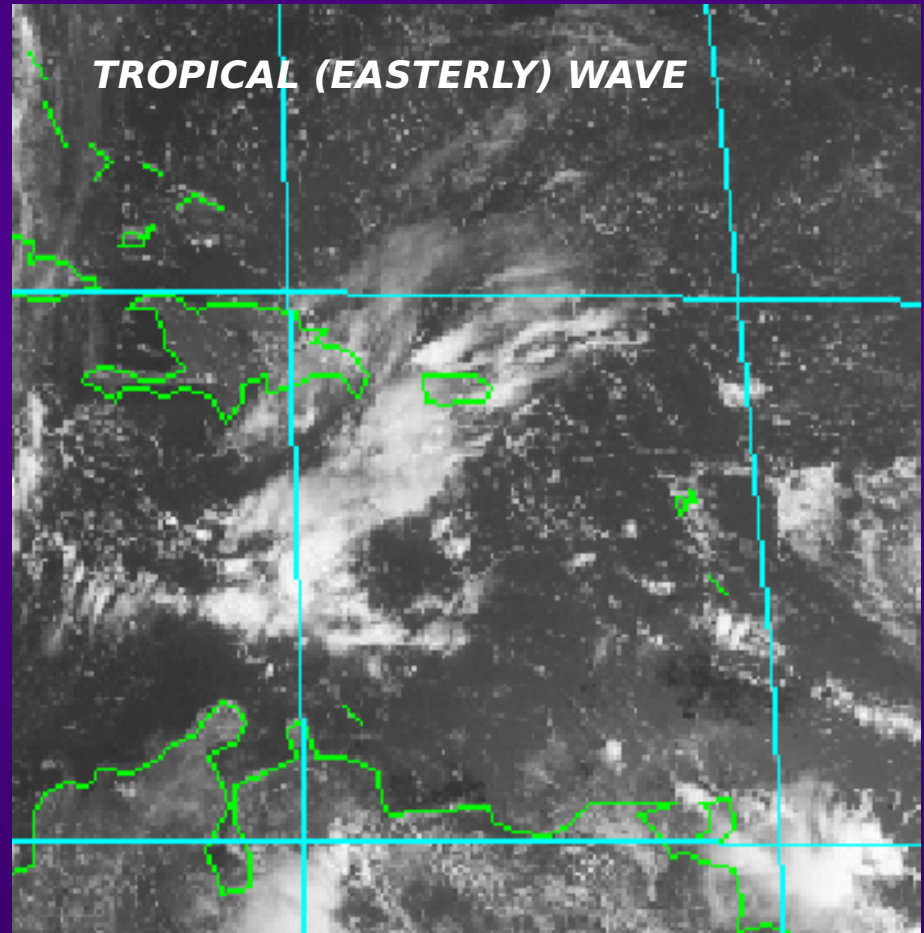
4.





TROPICAL (EASTERLY) WAVE

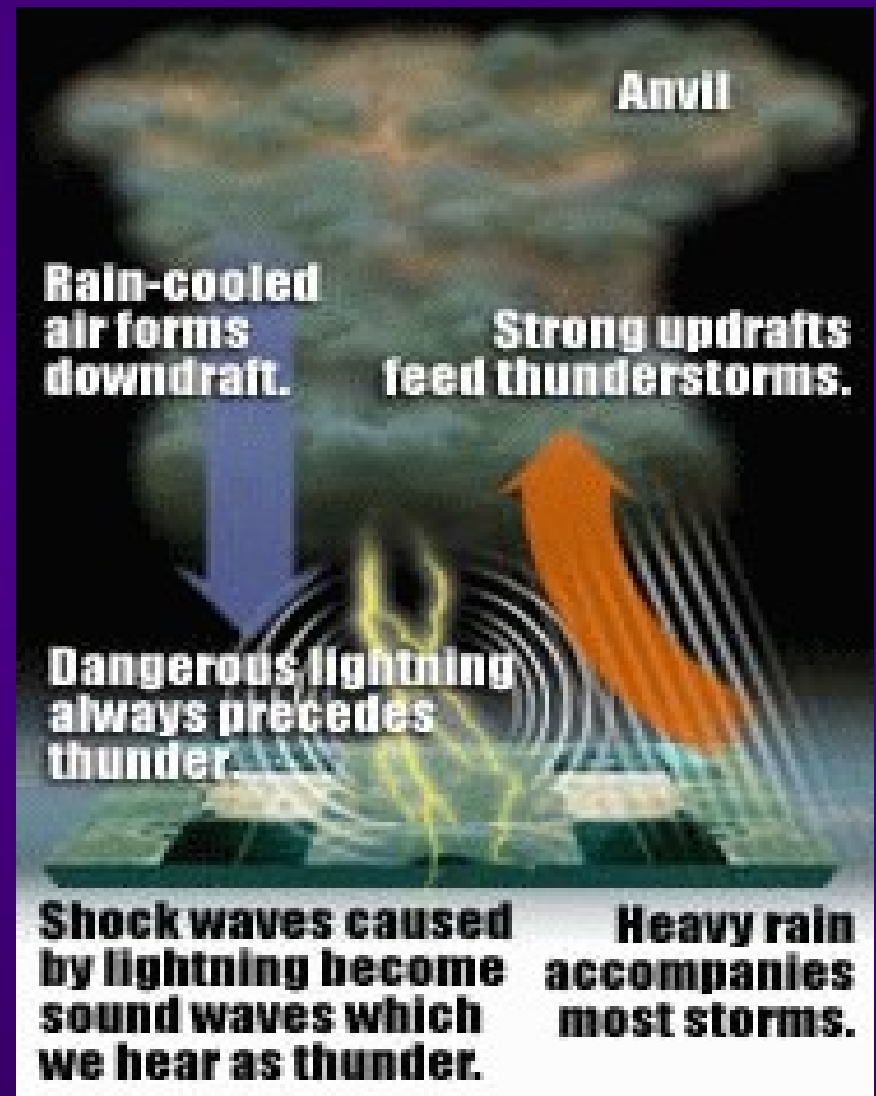
- ◆ **no significant winds or seas**
- ◆ **no defined surface circulation**

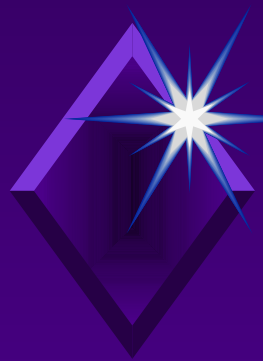




TROPICAL (EASTERLY) WAVE

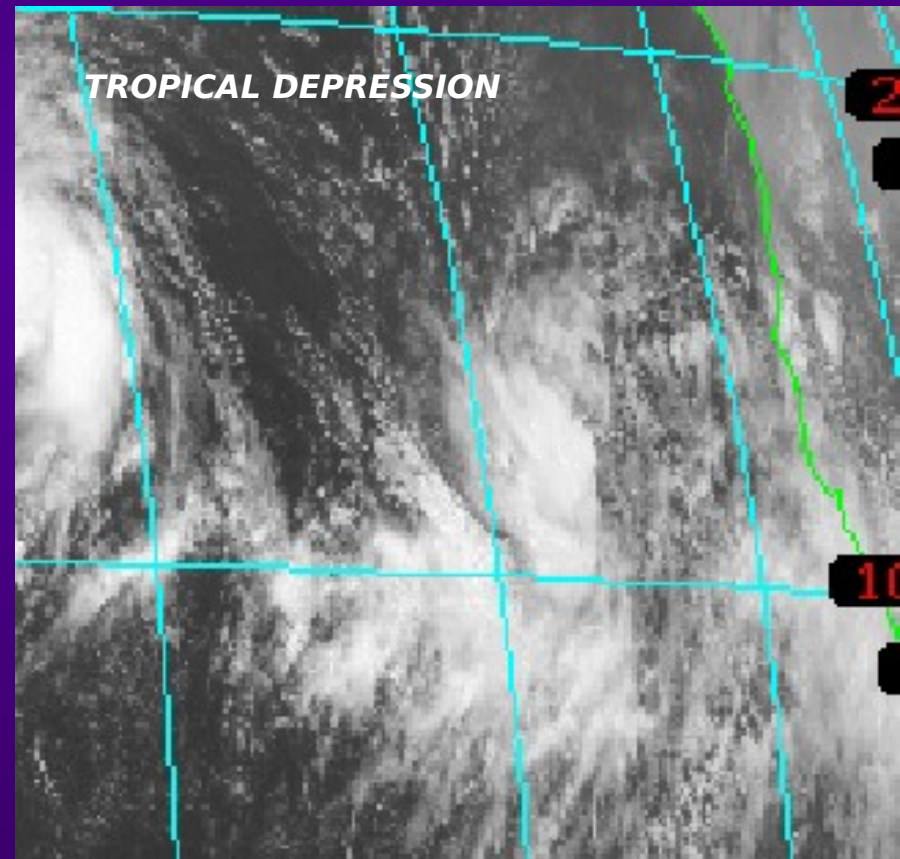
- ◆ identified by areas of convergence (thunderstorms) on surface charts and satellite imagery

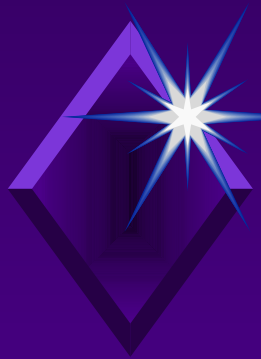




TROPICAL DEPRESSION *(Formative Stage)*

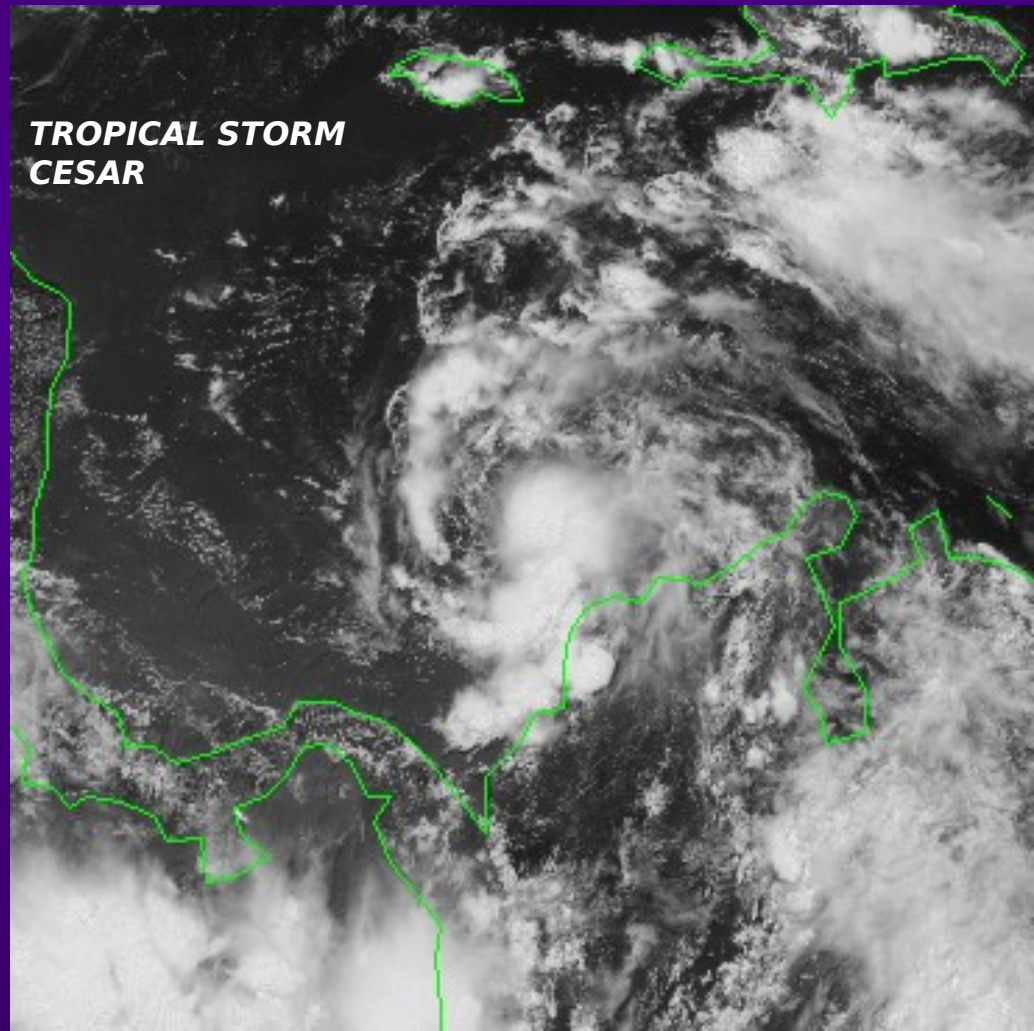
- ◆ winds < 34 kts
- ◆ tropical wave develops a **weak cyclonic circulation**
- ◆ identified by **thickening clusters of tstms** on satellite
- ◆ central **pressure falls rapidly** below 1002mb if system intensifies

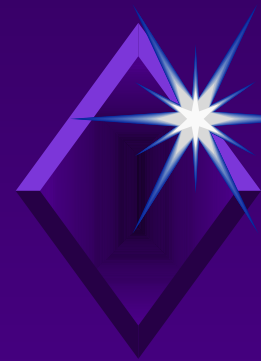




TROPICAL STORM *(Immature to Mature* *Stage)*

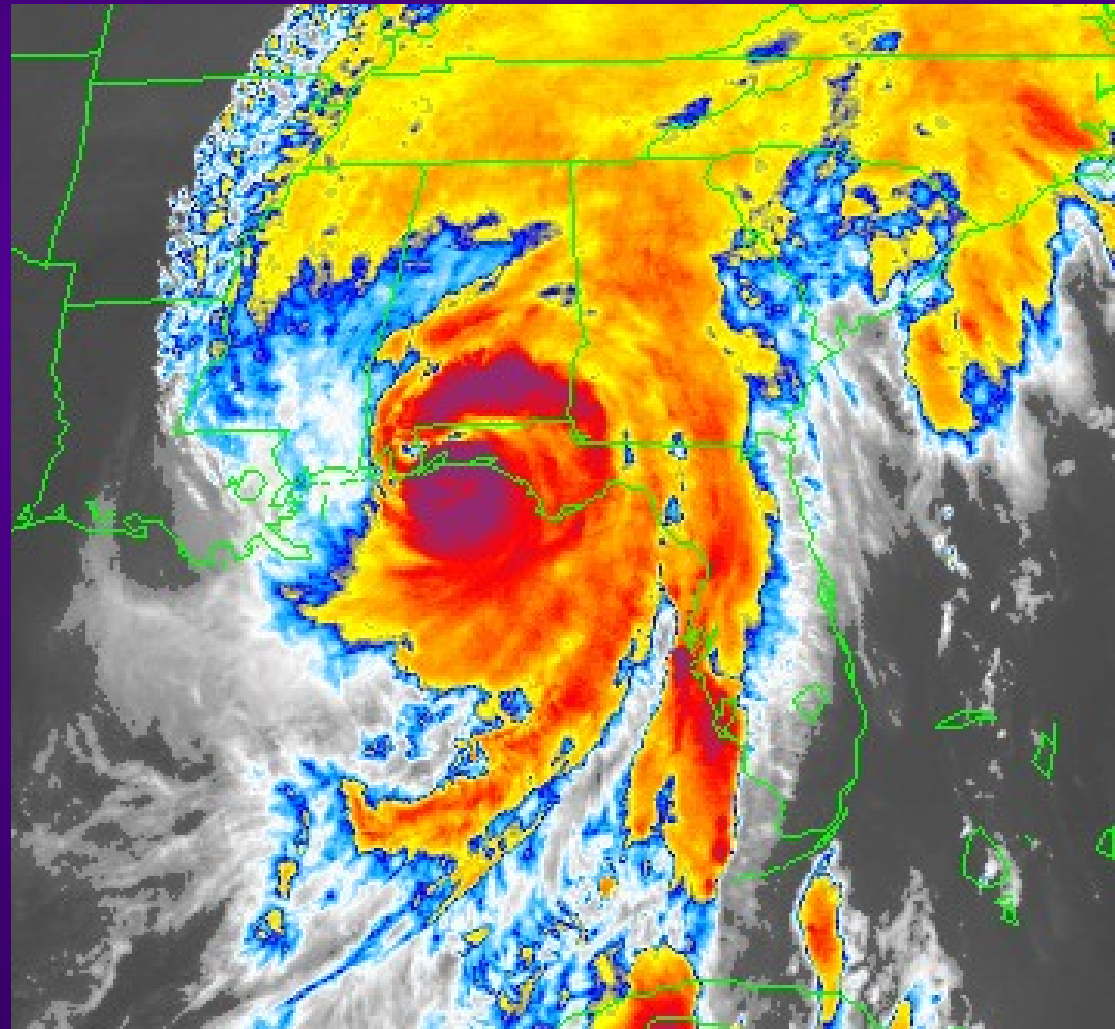
- ◆ winds 34 - 63 kts
- ◆ closed formation expands with **spiral bands becoming better organized**
- ◆ **increasing sea state** makes navigation near the center increasingly difficult and dangerous





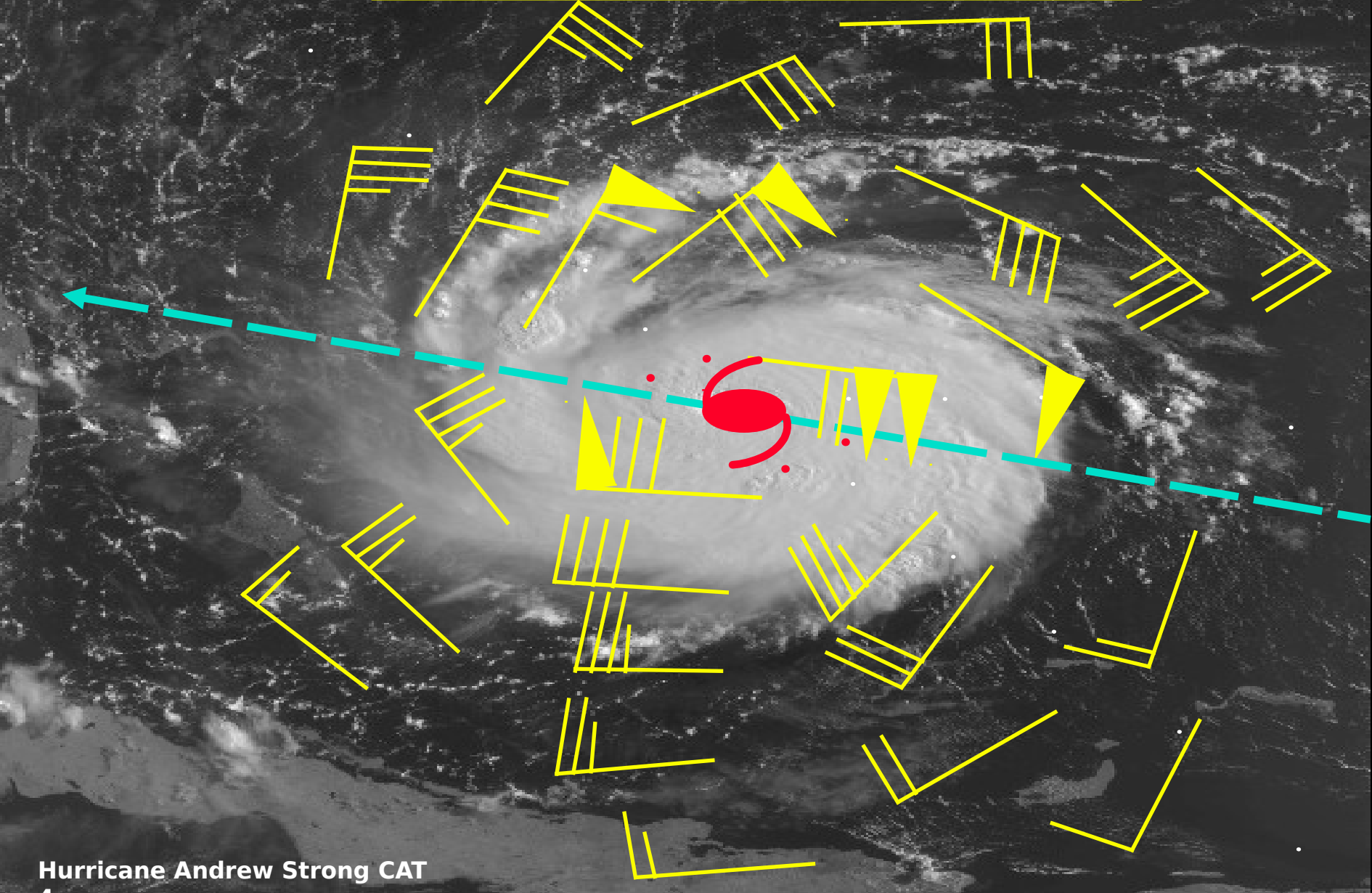
HURRICANE (Mature Stage)

- ◆ winds > 63 kts
- ◆ **DANGEROUSLY HIGH SEAS**
severely impairs navigation
- ◆ radius of strong winds may exceed **350 nm**
- ◆ Gale Force Winds extend out further in **right front quadrant** (typically 120 nm)

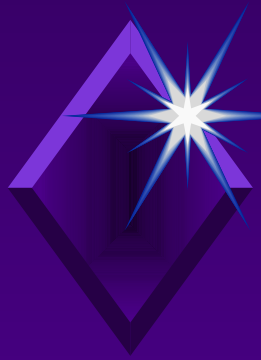


TROPICAL CYCLONE CHARACTERISTICS

Distribution of Surface Winds



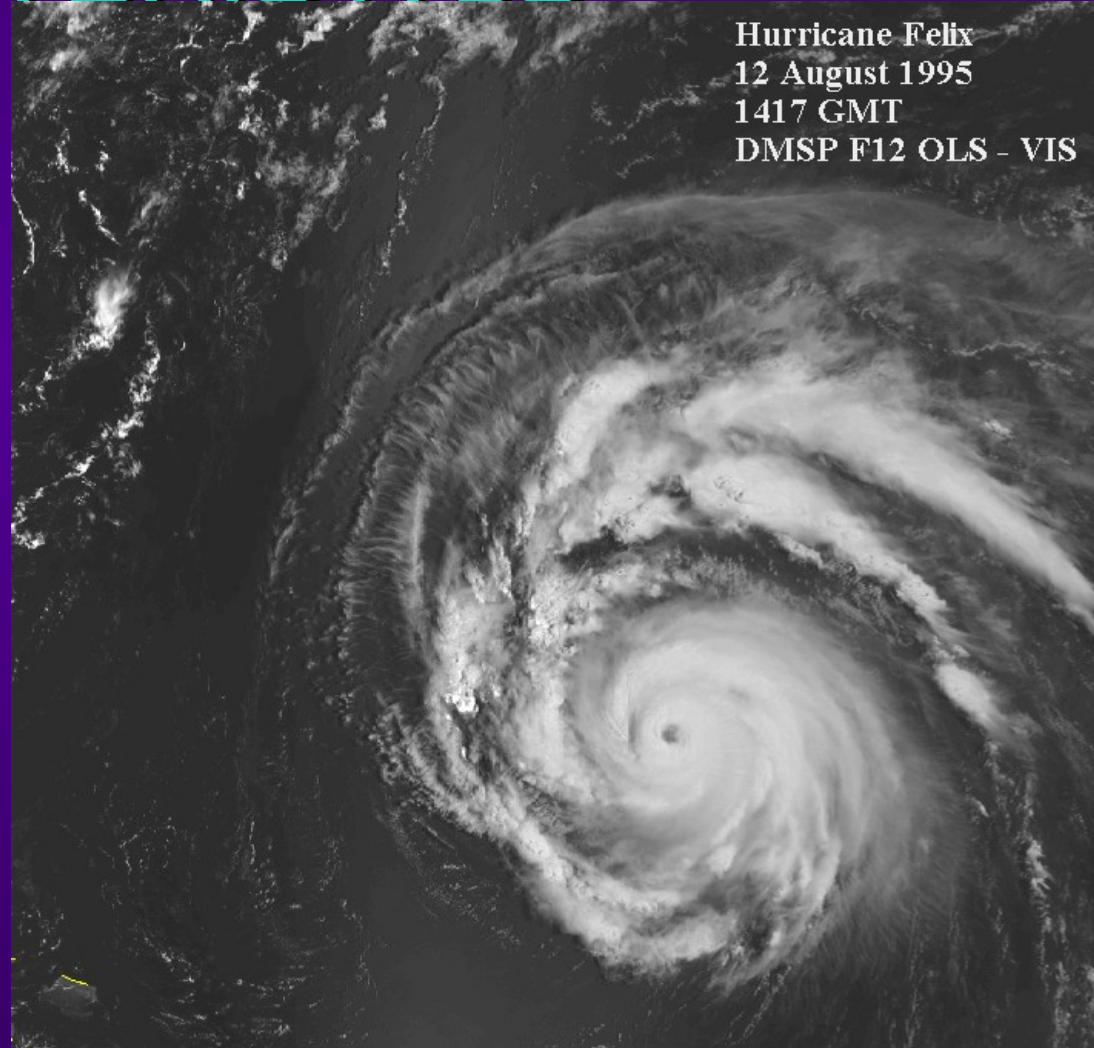
Hurricane Andrew Strong CAT



TROPICAL CYCLONE CHARACTERISTICS

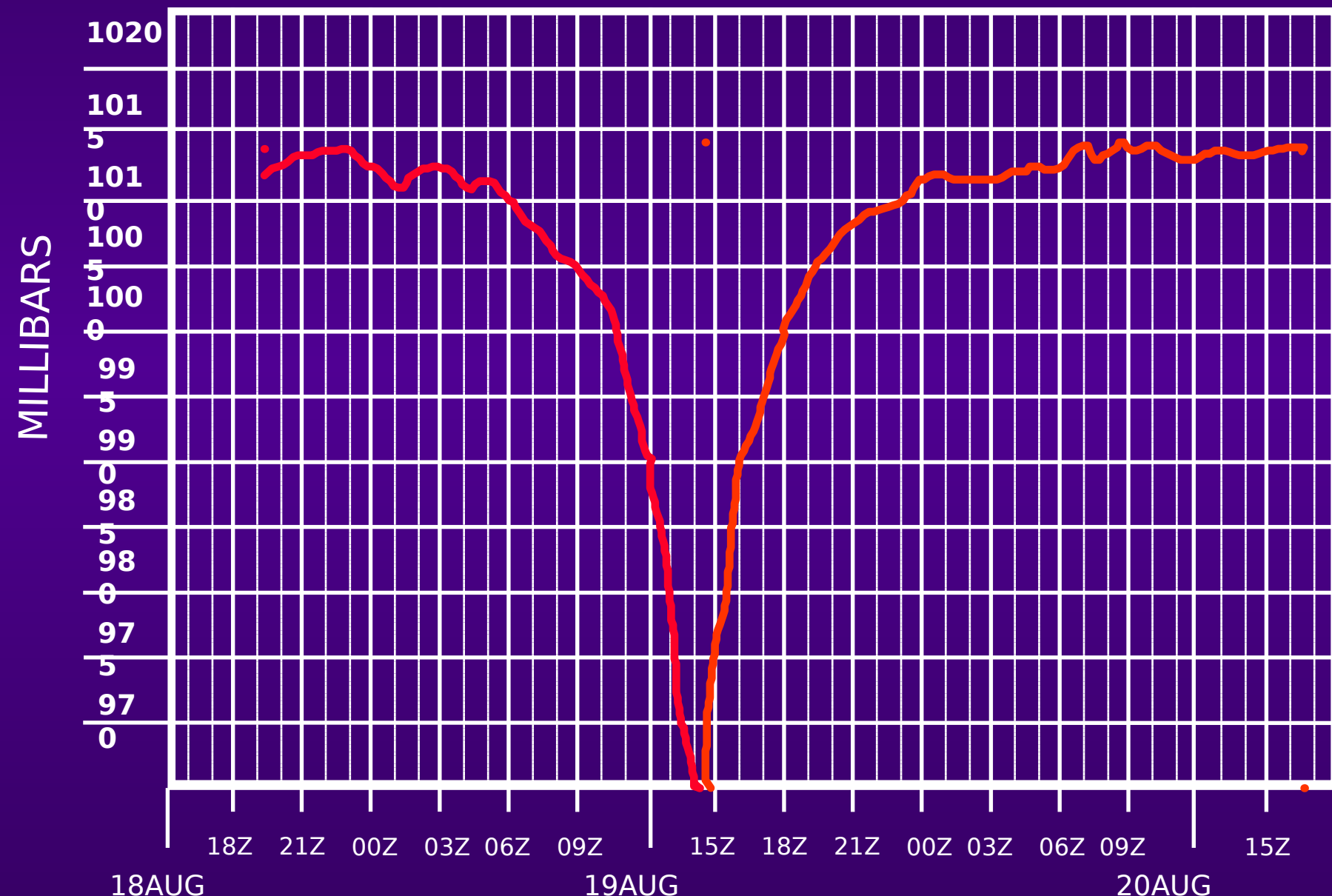
Feeder Bands (curved lines of convection) spiral inward to the Eye Wall. Some of the most violent weather (tornadoes/severe thunderstorms) occurs in these areas

“pumping
action”
announcing
approach of the
storm and as the
Tropical Cyclone

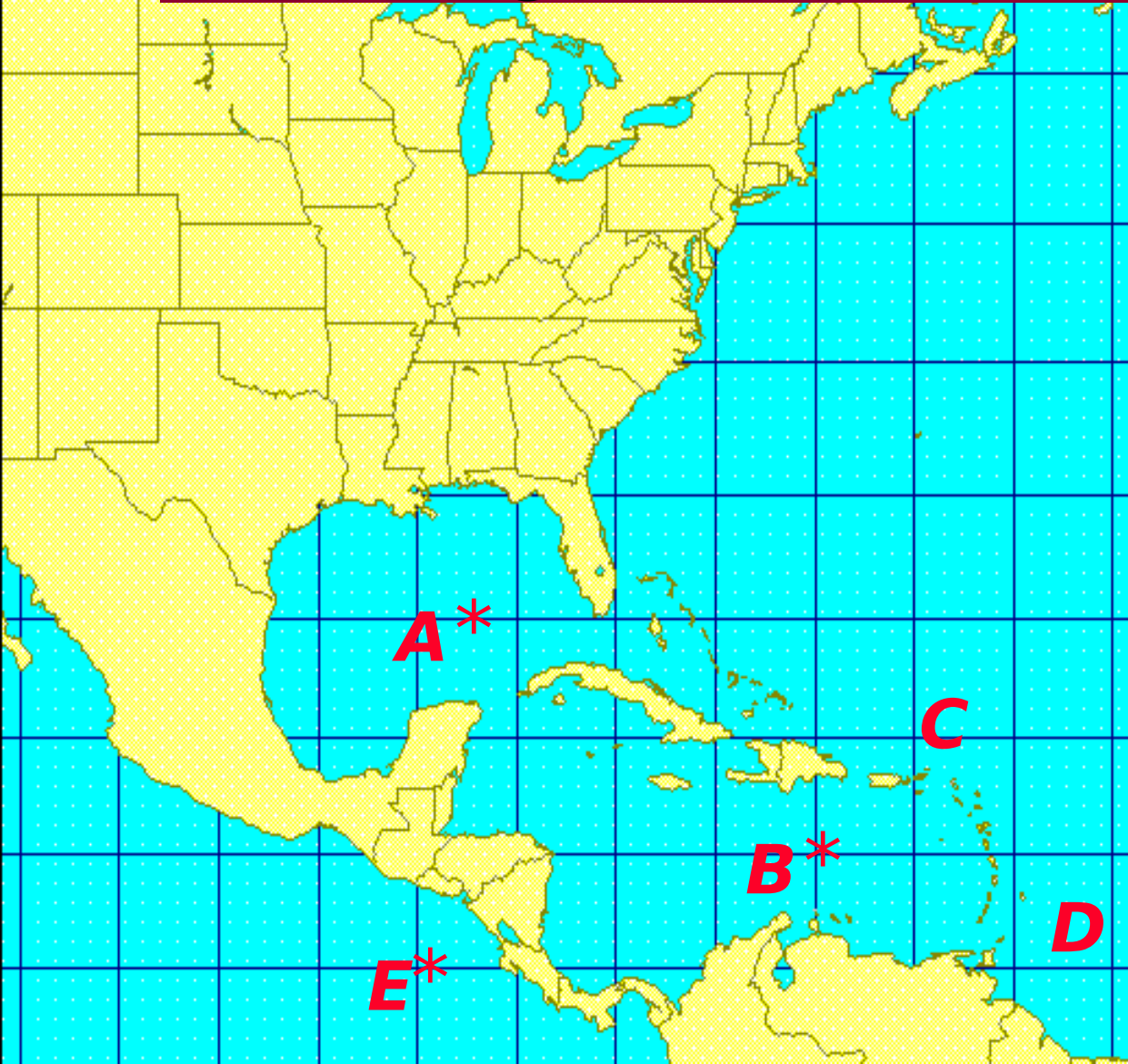


BAROGRAPH TRACE

Hurricane Bob 1991 NLMOD Newport



AREAS OF POTENTIAL DEVELOPMENT



A. GOMEX

B. CARIBBEAN

***C. TROPLANT
(<25 DEG
NORTH)***

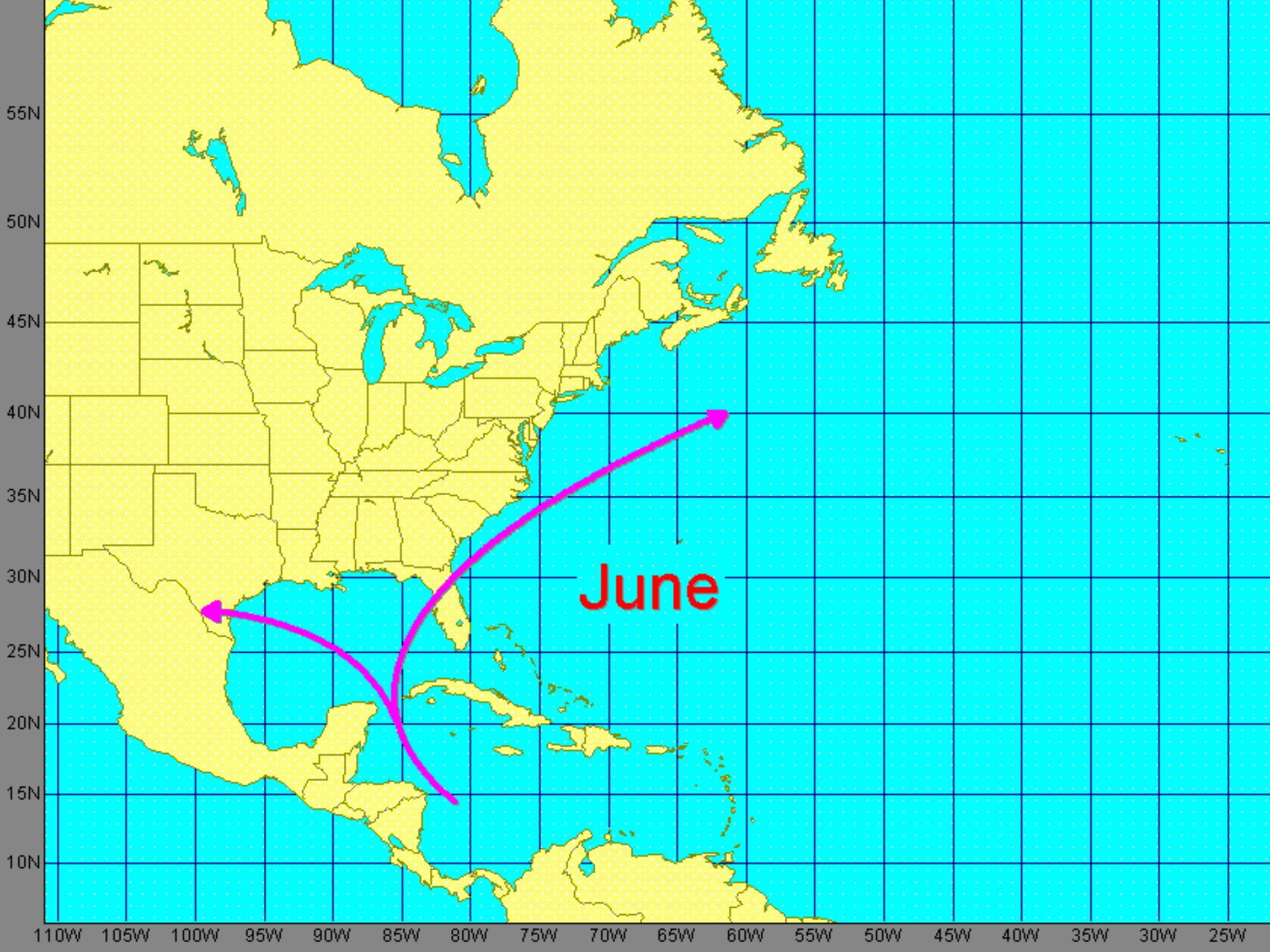
D. ITCZ

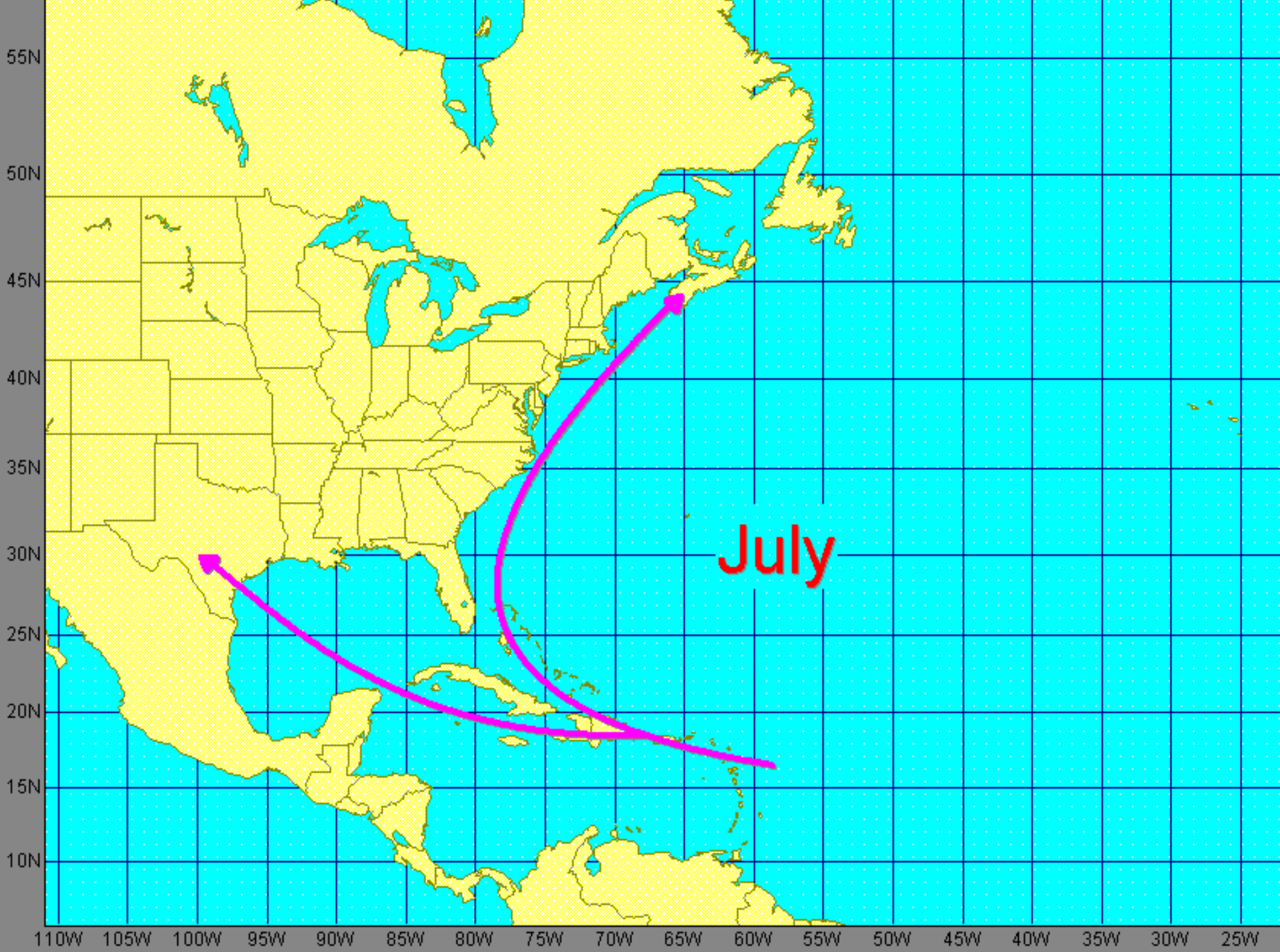
~~E.~~ EASTPAC

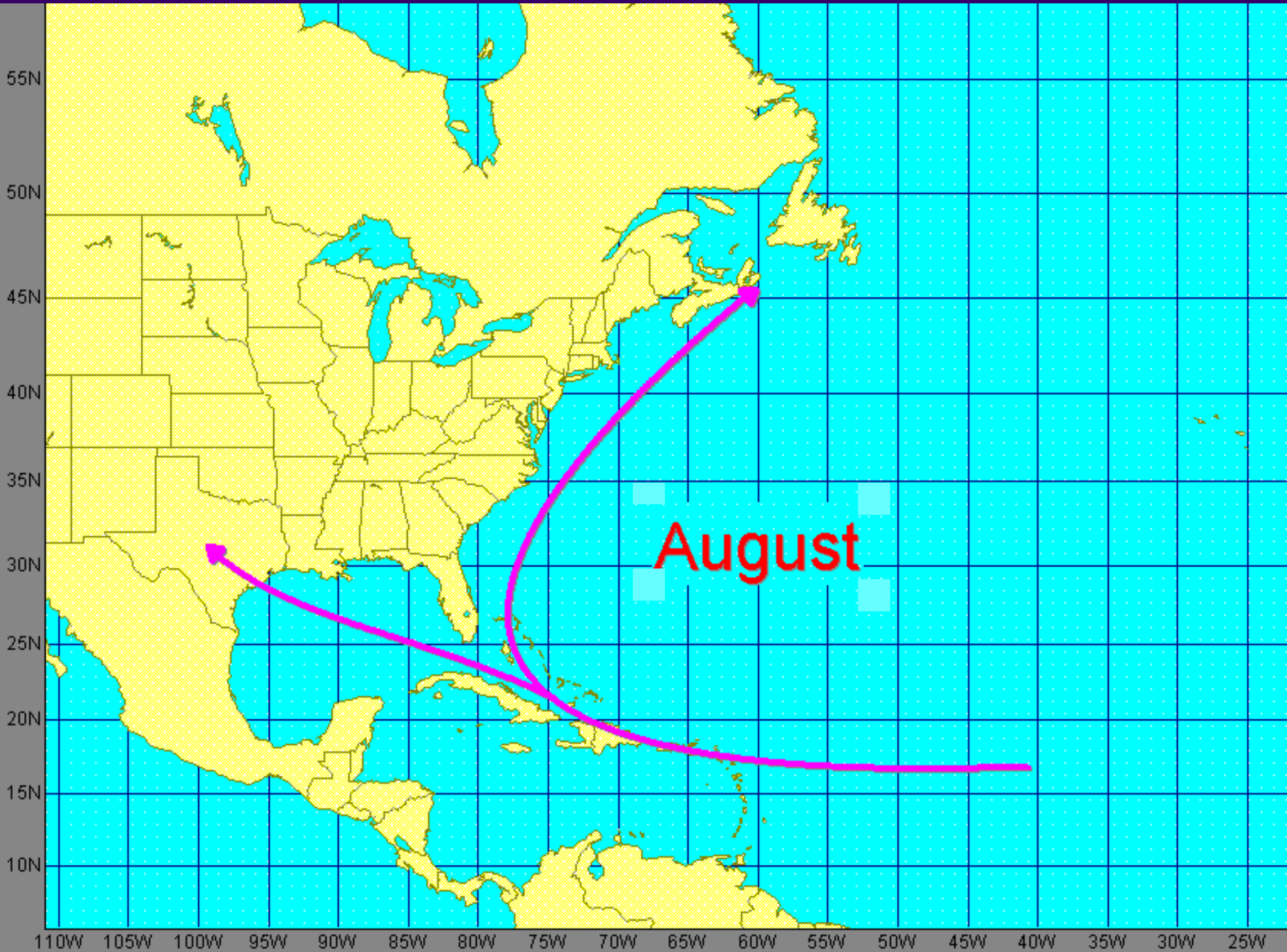
Early Season
Development

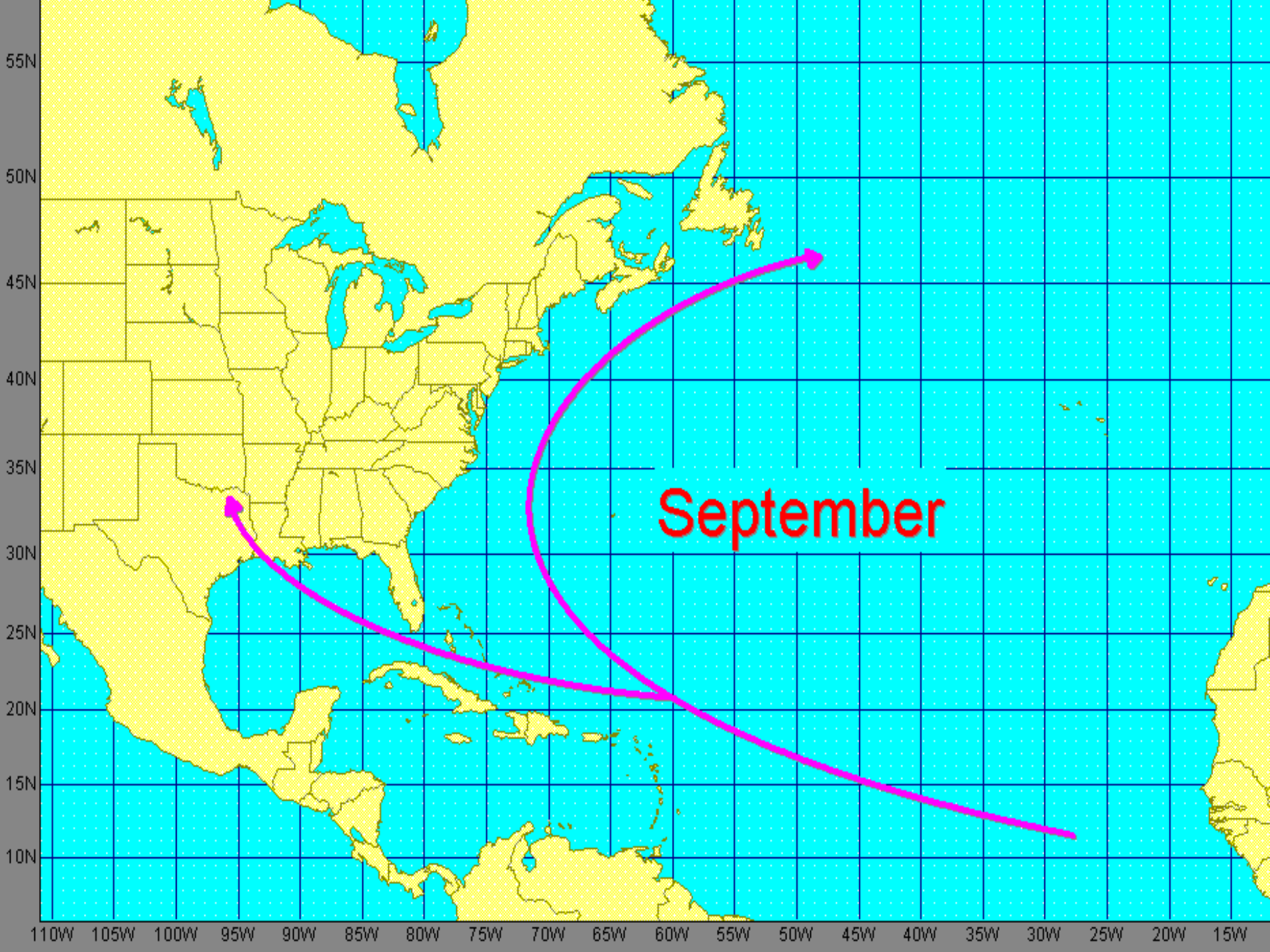


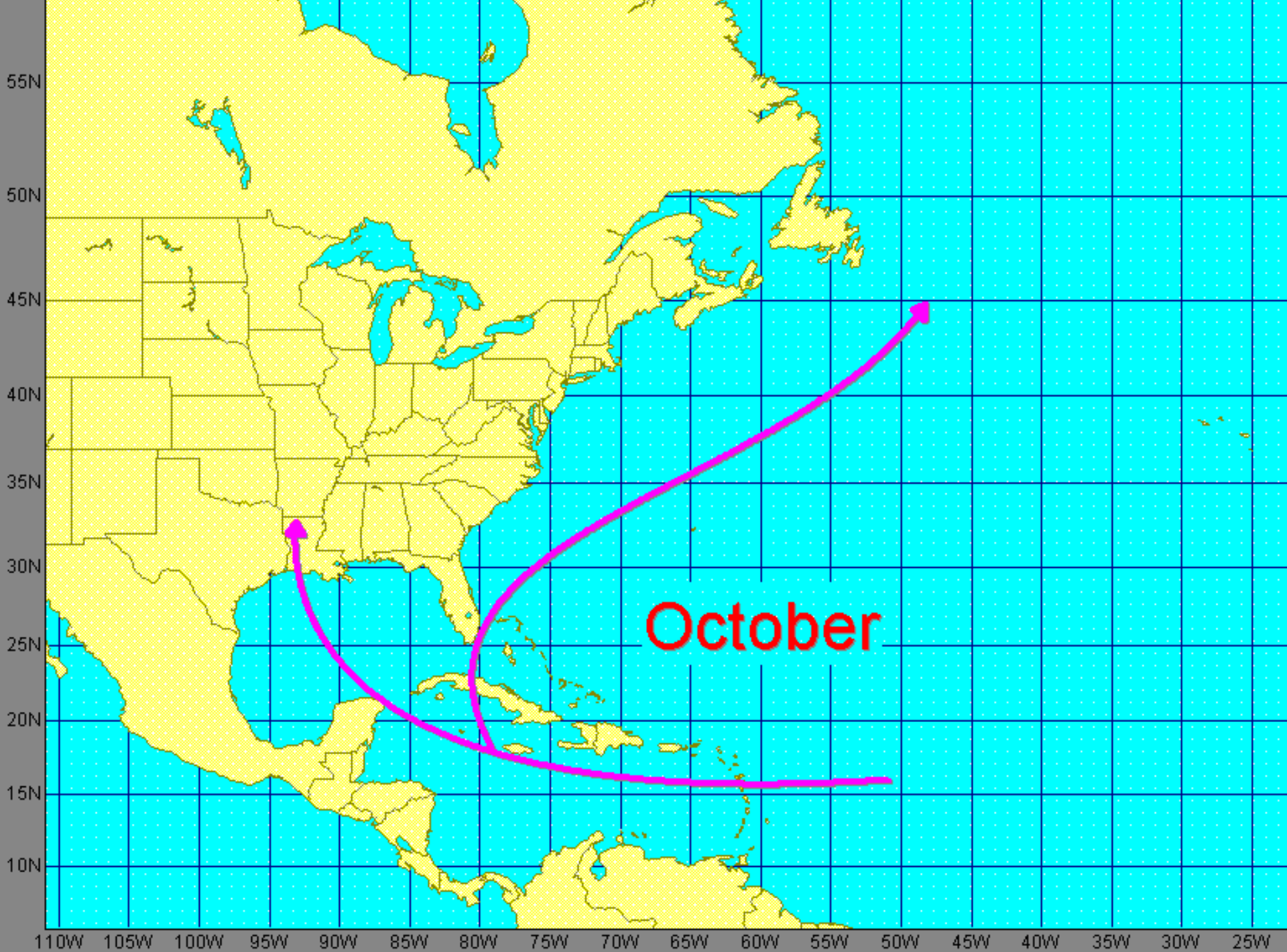
HURRICAN ESTORM TRACKS

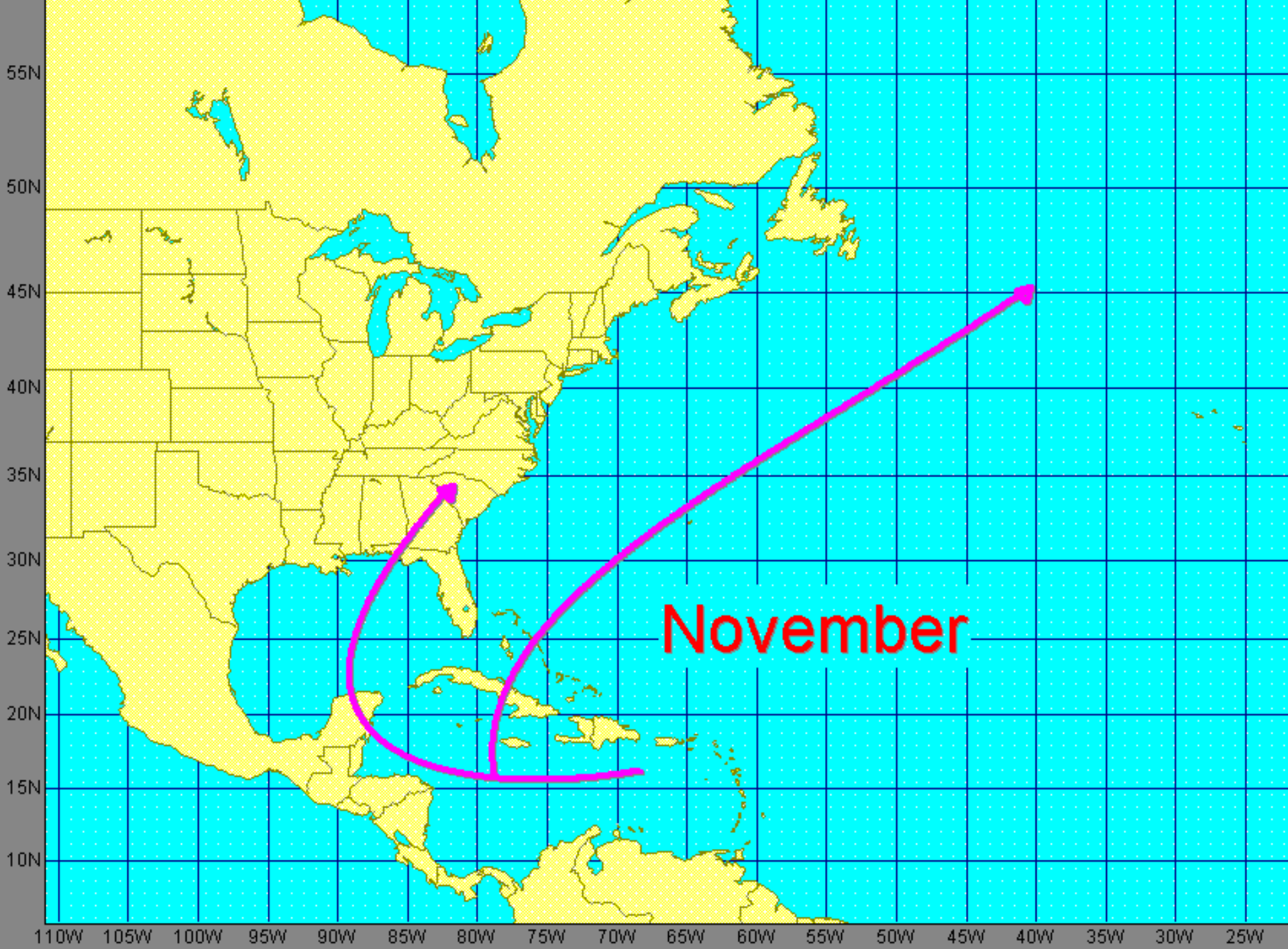














OPTIMUM TRACK SHIP ROUTING (OTSR)

A. Location - Naval Atlantic Meteorology and Oceanography Center, Norfolk (U-117)

Additional sites located at: Guam and Pearl Harbor

B. OTSR Missions:

- ◆ Safety of Sea
- ◆ Damage Avoidance
- ◆ Time/Fuel Economy



OTSR (con't)

C. OTSR Tropical Cyclone Duties and Responsibilities

◆ Issue:

- ◆ **Tropical Cyclone weather advisories**
- ◆ **Tropical Cyclone divert/evasion recommendations**
- ◆ **Condition of Readiness recommendations to shore commands**
- ◆ **Port Sortie/No Sortie recommendations to SOPA**
- ◆ **No Sortie recommendations**
- ◆ **Tropical Cyclone weather advisories once u/w**
- ◆ **Return to Port recommendations**



TROPICAL SEASON AT NAVLANTMETOCEN

1. OTSR Tropical Router

- ◆ locate and maintains plot of all units underway south of 30N (**SHIP OBS, MOVREPS**, Joint Maritime Information System (JMCIS), Blue Force Locator, phone calls)
- ◆ monitors real-time satellite imagery for convection, focuses on areas favorable for development first
- ◆ monitors upper level wind flow for divergence (high pressure aloft)
- ◆ watches for low level cyclonic circulation



TROPICAL SEASON *(cont)*

NLMOC will issue a **Tropical Cyclone Formation Alert** if necessary for units in the area of potential development.

2. Tropical Cyclone Warnings begin

3. CDO NLMOC and the Tropical Prediction Center coordinate via Hotline (conference calls 4 times/day)



TROPICAL SEASON *(cont)*

4. Tropical Prediction Center directs CARCAH to fly on system west of 40W longitude.

CARCAH: (Chief Aerial Recon Coordinator All Hurricanes) **MILITARY** POC for NHC, 53rd Weather Recon Squad (C-130's from Keesler) and NOAA Corps Aircraft Ops Center (P-3's and Gulf Stream 4 - southern Florida)



TROPICAL SEASON *(cont)*

5. **OTSR** issues ***weather advisory*** to ships in close proximity, or to SOPA in close proximity
6. **OTSR** issues ***Tropical Cyclone Evasion*** recommendations
7. **OTSR** issues ***Sortie/No Sortie*** recommendations



TROPICAL SEASON *(cont)*

8. NLMOC issues ***Condition of Readiness*** recommendations to Shore Commands

9. OTSR issues ***Return to Port***



SHIPS AT SEA



MONITORING THE STORM

- ◆ **NLMOC/TPC Warnings/Bulletins**
- ◆ **Joint Maritime Command Information System (JMCIS) METOC Overlays**
- ◆ **OTSR/NLMOC Operations Watch Floor
(757-444-4044 - DSN 564)**
- ◆ **Satellite Imagery (NFAX/HOMEPAGE/INTERNET)**
- ◆ **NLMOC Homepage SIPRNET <http://206.36.246.130>
NIPRNET
<http://192.207.216.107>
<http://www.nlmoc.navy.mil>**



WARNING'S

- ◆ **Frequency** (every 6 hours, 03Z, 09Z, 15Z, 21Z)
 - ◆ **Methods of Receiving Warning**
 - ★ 1. Autodin addressed to CAD HURRIWARNLANT (regular message traffic)
 - 2. JMCIS
 - 3. Autopoll (757-444-0963)
 - 4. NFAX (8080 khz, etc...)
 - 5. Tropical Warning Voice Recording (757-444-7736)
 - ★ 6. Tropical Warning Voice Recording (757-444-7736)
- <http://192.207.216.107>)
- <http://www.nlmoc.navy.mil>
- NIPRNET

WARNING'S

**Hurricane Hortense (08L) warning NR 42
03 Active Tropical Cyclone in the North Atlantic
Max sustained winds based on one-minute average**

Warning Position:

141800Z --- 34.0N7 065.4W5

Movement past six hours - 315 degrees at 07 KTS

Position accurate to within 30NM

**Position based on center located by a combination
of satellite and synoptic data**

Present wind distribution:

Max sustained winds 075 KTS gusts 090KTS

**Radius of 65 KT winds - 000 NM west semicircle
125 NM east semicircle**

**Radius of 50 KT winds - 50 NM west semicircle
150 NM east semicircle**

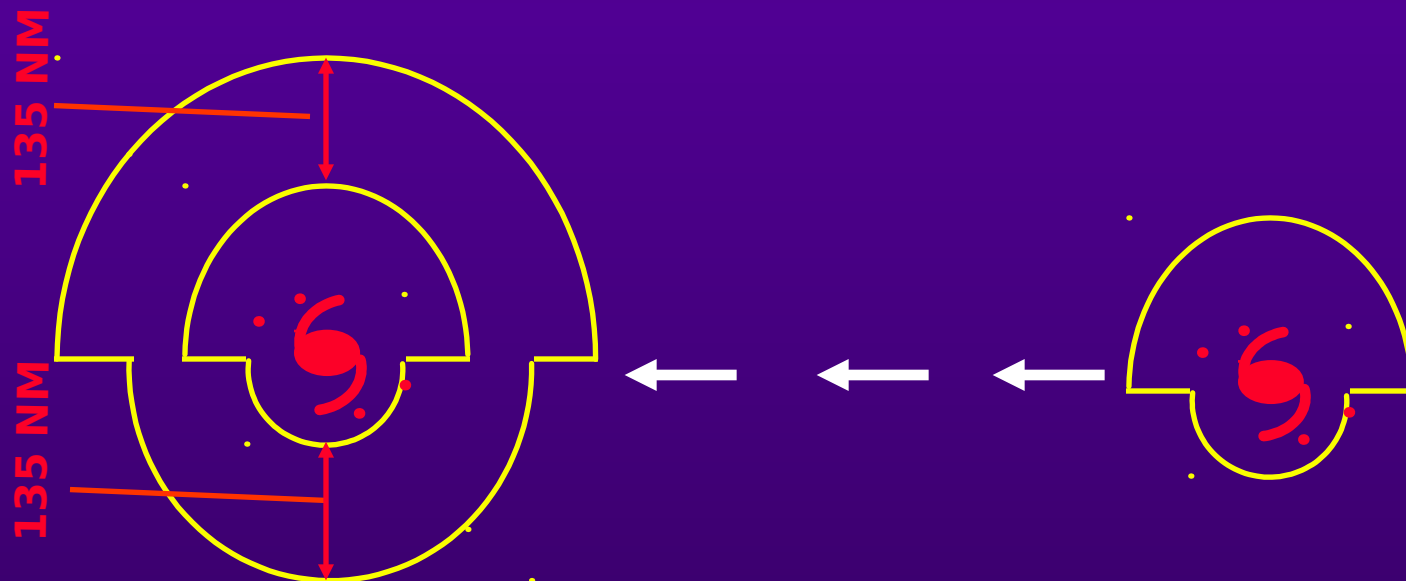
**Radius of 35 KT winds - 75 NM west semicircle
225 NM east semicircle**



WARNING'S

Upon Receipt of Warning:

- 1 Plot the current and forecasted 24 hour storm position, and the forecasted radius of 35 kt winds.
- 2 Using a compass extend the radius of the forecasted 24 hour 35 kt wind band by 135 NM.



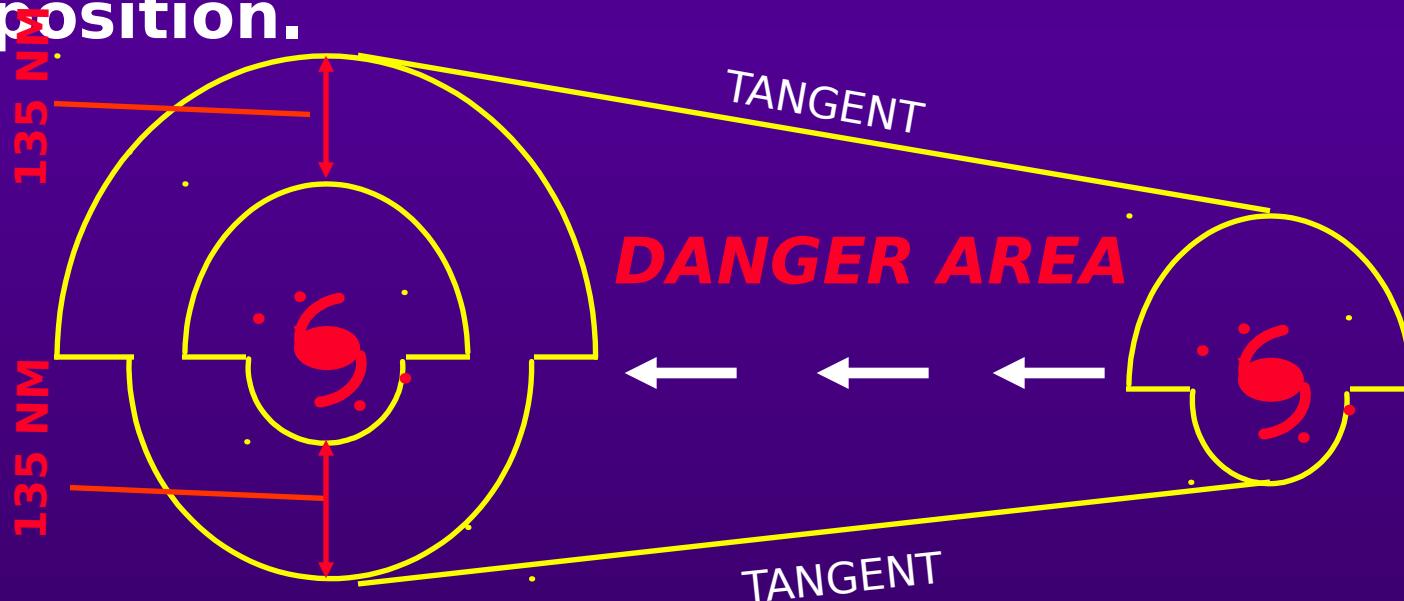
24 HR FORECAST POSITION

CURRENT POSITION



WARNING'S

- 3 Draw tangents relative to the direction of the storm from the 35 kt radius (current position) to the outermost radius at the 24 hr forecast position.

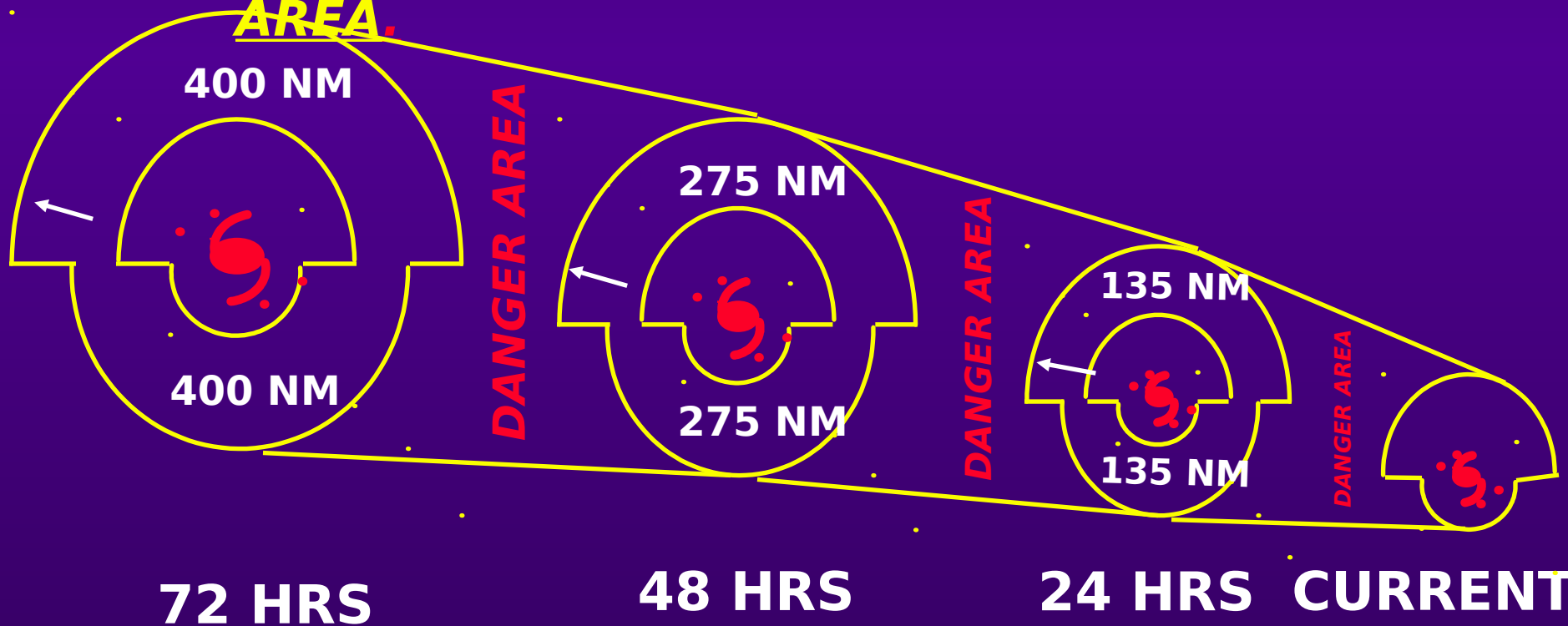


24 HR FORECAST POSITION

CURRENT POSITION

UPON RECEIPT OF WARNING

- 4 Use the same procedure for the 48 and 72 hr forecast positions, however, use 275 and 400 NM radii/respectively, in lieu of the 135 NM value. Avoid the **DANGER AREA**.





TROPICAL CYCLONE EVASION

Rule #1:

Remain far enough away from the Tropical Cyclone **so the following rules are not required.**



TROPICAL CYCLONE EVASION

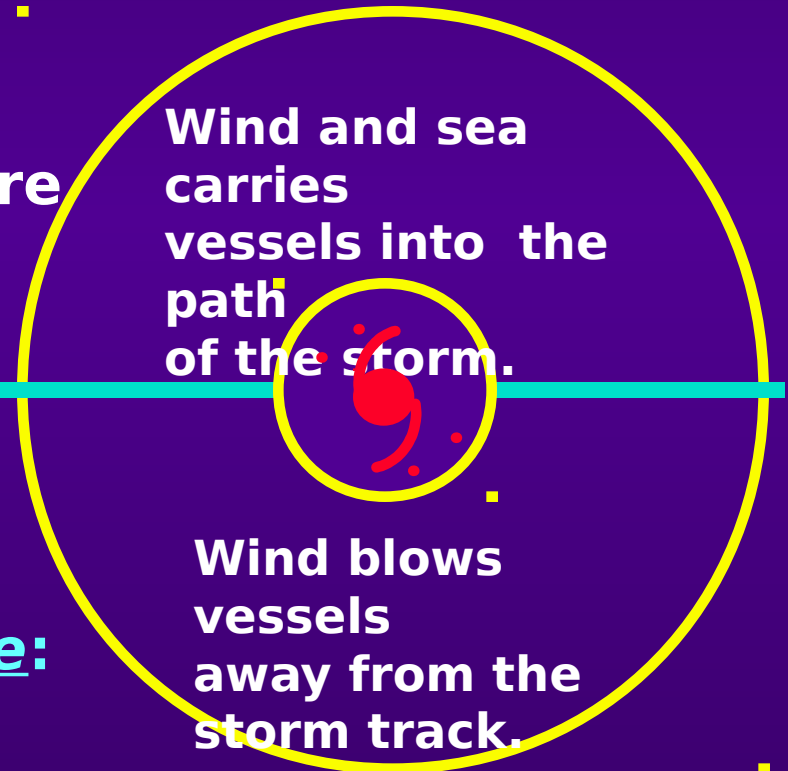
Storm's location relative to own ship's position:

Dangerous semi-circle:

Wind greater due to pressure augmented by the forward motion of the storm.

"Less Dangerous" semi-circle:

Wind decreased by forward motion of the storm.



TROPICAL CYCLONE EVASION

Ship in the Dangerous (right) semi-circle:

1. Maneuver ship so relative wind is from 045 degrees to starboard.
2. Continually hold course with respect to relative wind, making best way possible.

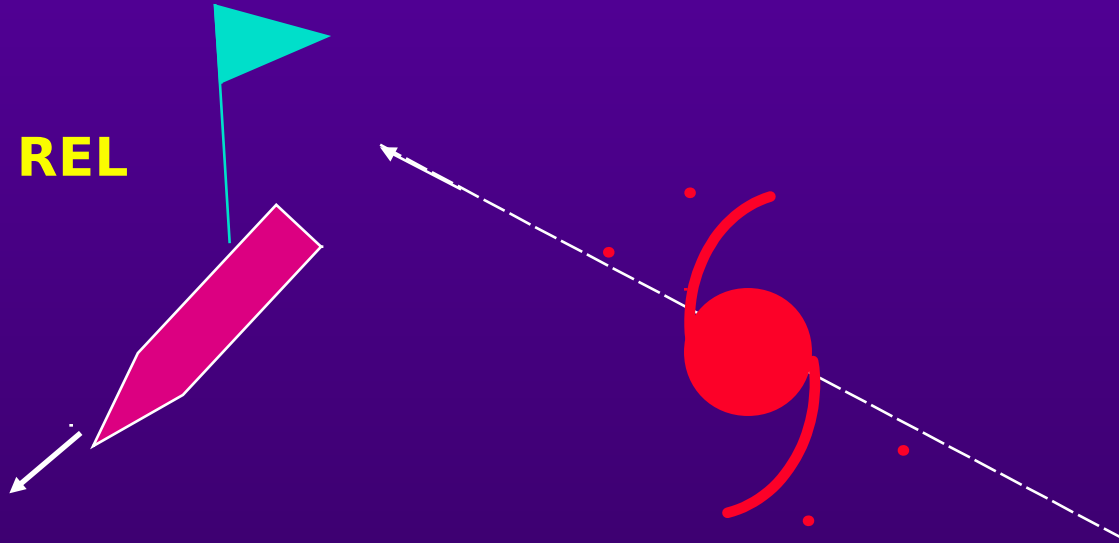


TROPICAL CYCLONE EVASION

Ship in the “Less Dangerous” (left) semi-circle:

1. Maneuver ship so that relative wind is from 135 degrees to starboard.
2. Continually hold course with respect to relative wind, and make best way possible.

135 DEG REL



SHIP IS HEADED IN A MORE
FAVORABLE DIRECTION



TROPICAL CYCLONE EVASION

**157 DEG
REL**

**BEHIND CENTER (ON STORM
TRACK)**

**Avoid center by best practical
course (storm may recurve).**

**AHEAD OF CENTER (ON STORM
TRACK)**

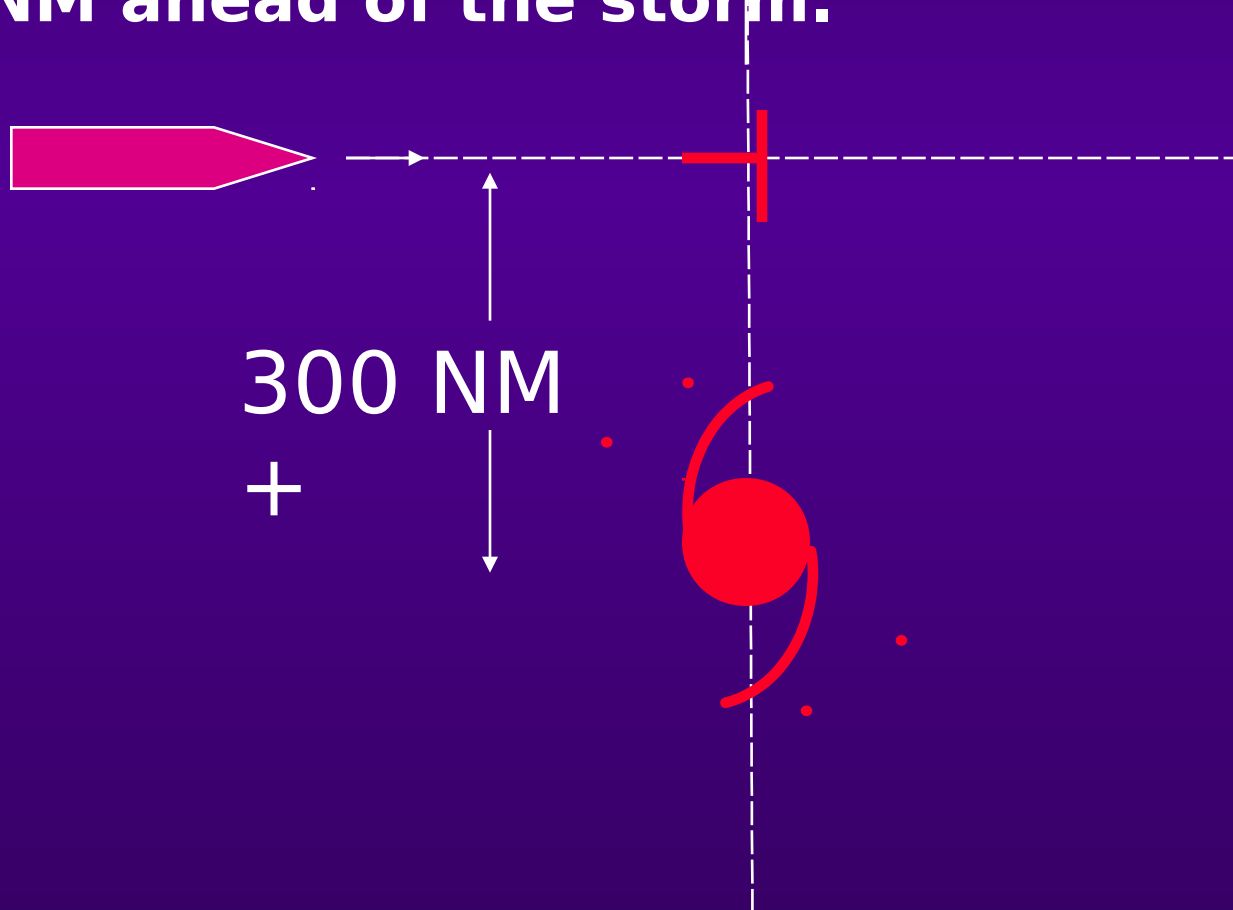
**Maneuver ship so that relative wind
is 157 degrees relative, hold course
and speed**





TROPICAL CYCLONE EVASION

DO NOT CROSS THE "T" unless the ship is
> 300 NM ahead of the storm.

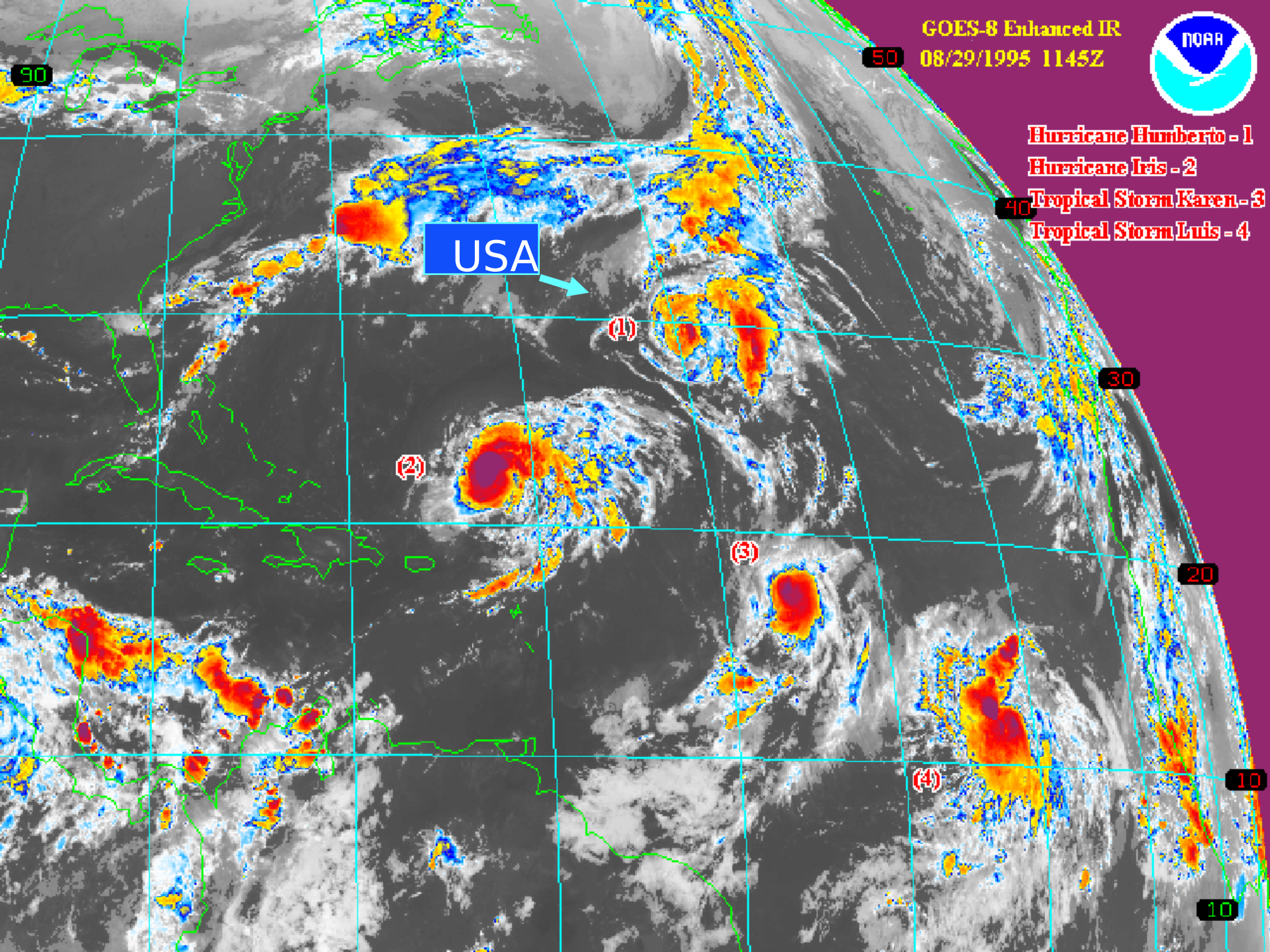


GOES-8 Enhanced IR
08/29/1995 1145Z



Hurricane Humberto - 1
Hurricane Iris - 2
Tropical Storm Karen - 3
Tropical Storm Luis - 4

USA





TROPICAL CYCLONE EVASION

Summary:

- ◆ Tropical Cyclones present one of the most serious threats to vessels at sea.
- ◆ Monitor warnings and advisories to prevent an encounter with a Tropical Cyclone.
- ◆ When a Tropical Cyclone is encountered, it becomes **ESSENTIAL** that you prepare the vessel for heavy weather in sufficient time to minimize potential damage to the vessel.

★ **REQUEST OTSR DURING TROPICAL SEASON**





SHIPS IN PORT/ SHORE COMMANDS



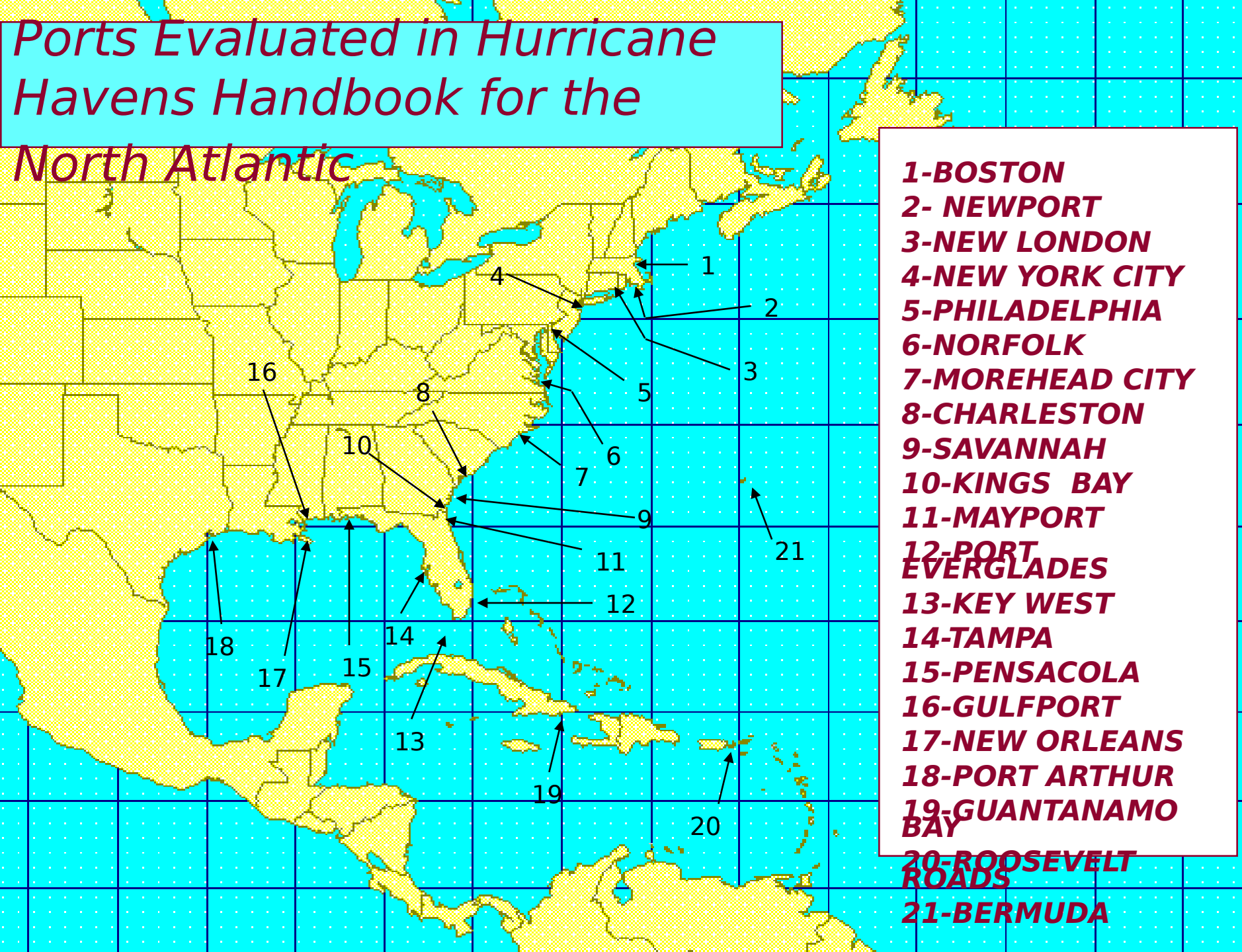
MONITORING THE STORM

- ◆ **NLMOC/NHC Warnings/Bulletins**
- ◆ **Joint Maritime Command Information System (JMCIS) METOC Overlays**
- ◆ **OTSR/Watch Floor (757-444-7750) (DSN 564)**
- ◆ **Tropical Cyclone Voice Recording (757-444-7356)**
- ◆ **Satellite Imagery**
- ◆ **NLMOC Homepage SIPRNET**
<http://206.36.246.130>

NIPRNET

<http://192.207.216.107>

Ports Evaluated in Hurricane Havens Handbook for the North Atlantic





SORTIE TO SEA

Factors determining sortie/no sortie:

- ◆ **Storm Intensity, Size, Strength, and Speed**
- ◆ **Probability of Hit (synoptics, angle of approach)**
- ◆ **## of vessels, size, speed**
- ◆ **Time window to clear last vessel**
- ◆ **Vessel Route (safe, heavy seas, etc...)**

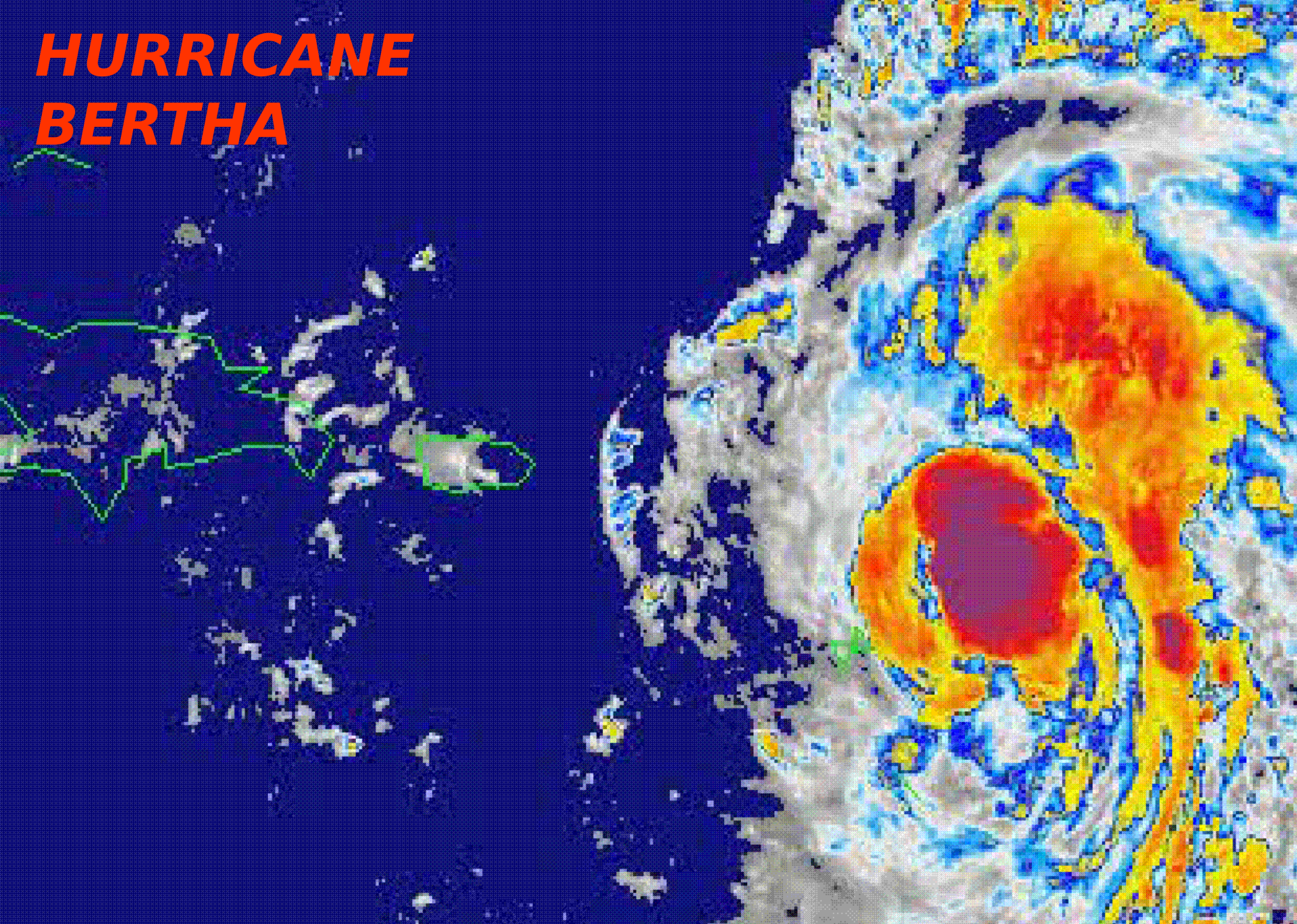


SORTIE TO SEA

OTSR Sortie Recommendation:

- ◆ **contents**
- ◆ **24 hours prior to onset of gale force winds**
- ◆ **follow-up (advisories, evasion recommendations, return to port)**

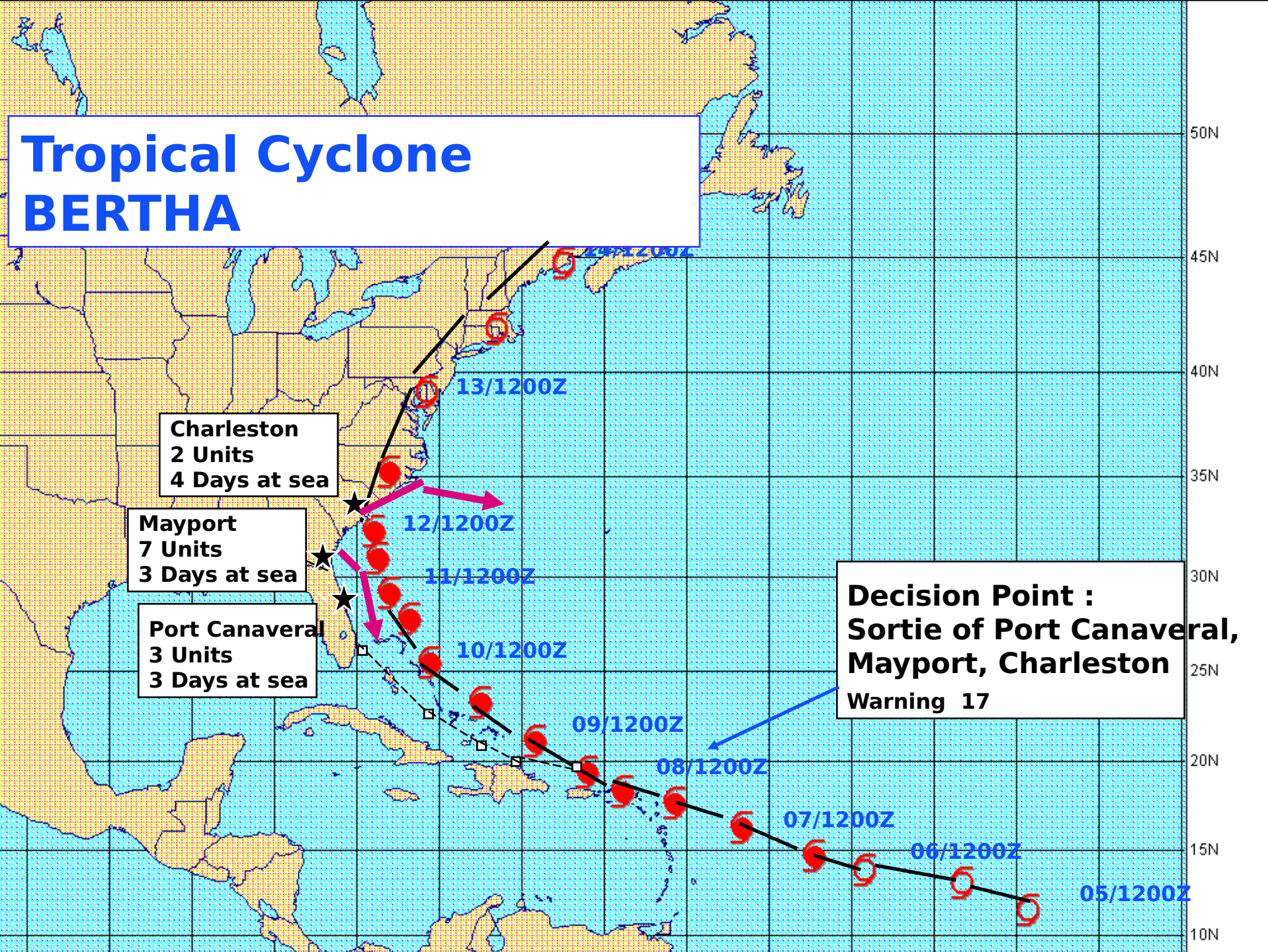
HURRICANE BERTHA



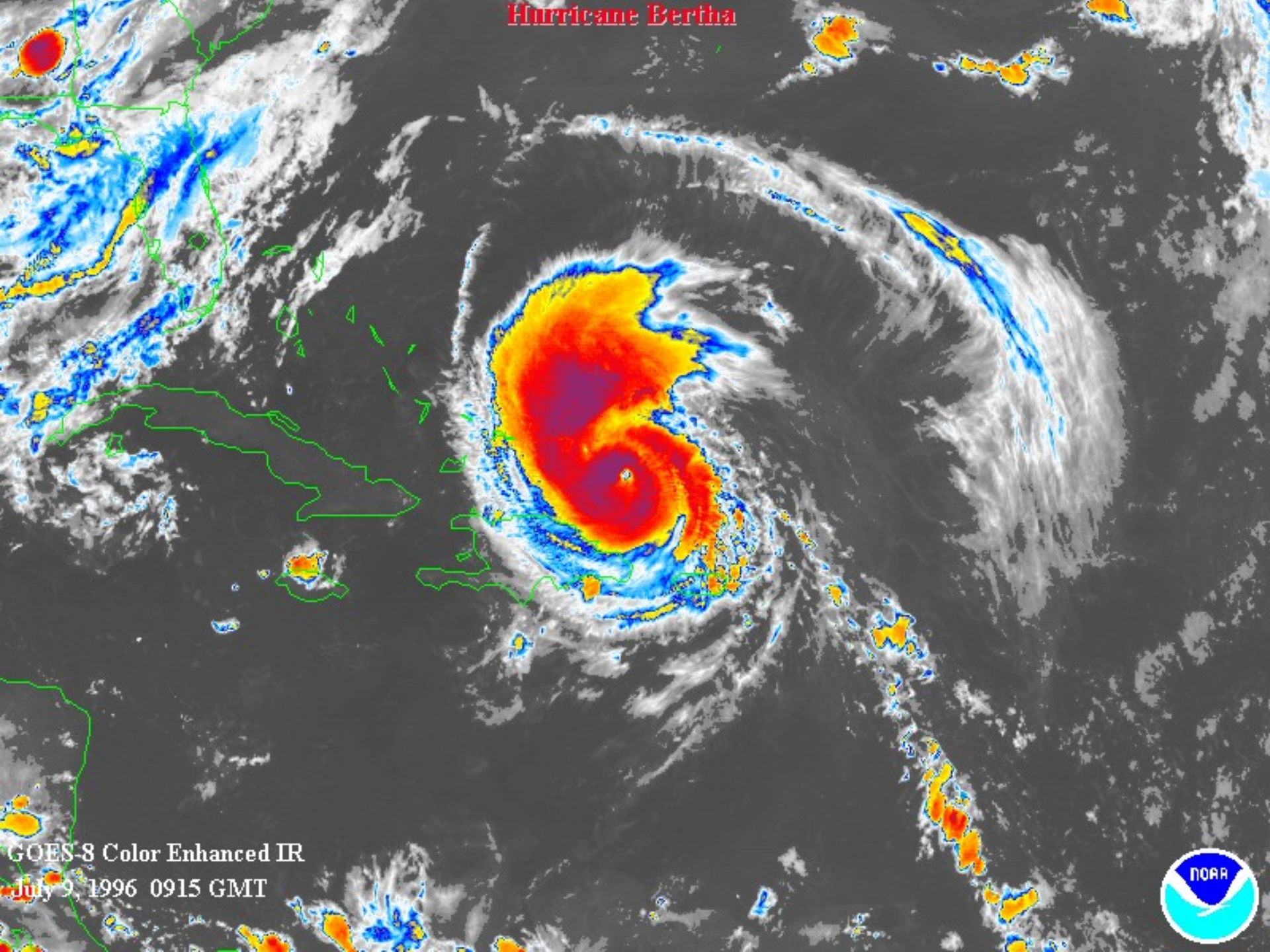
0004 G-8 IMG

04 7 JUL 96189 234500 05

Tropical Cyclone BERTHA



Hurricane Bertha



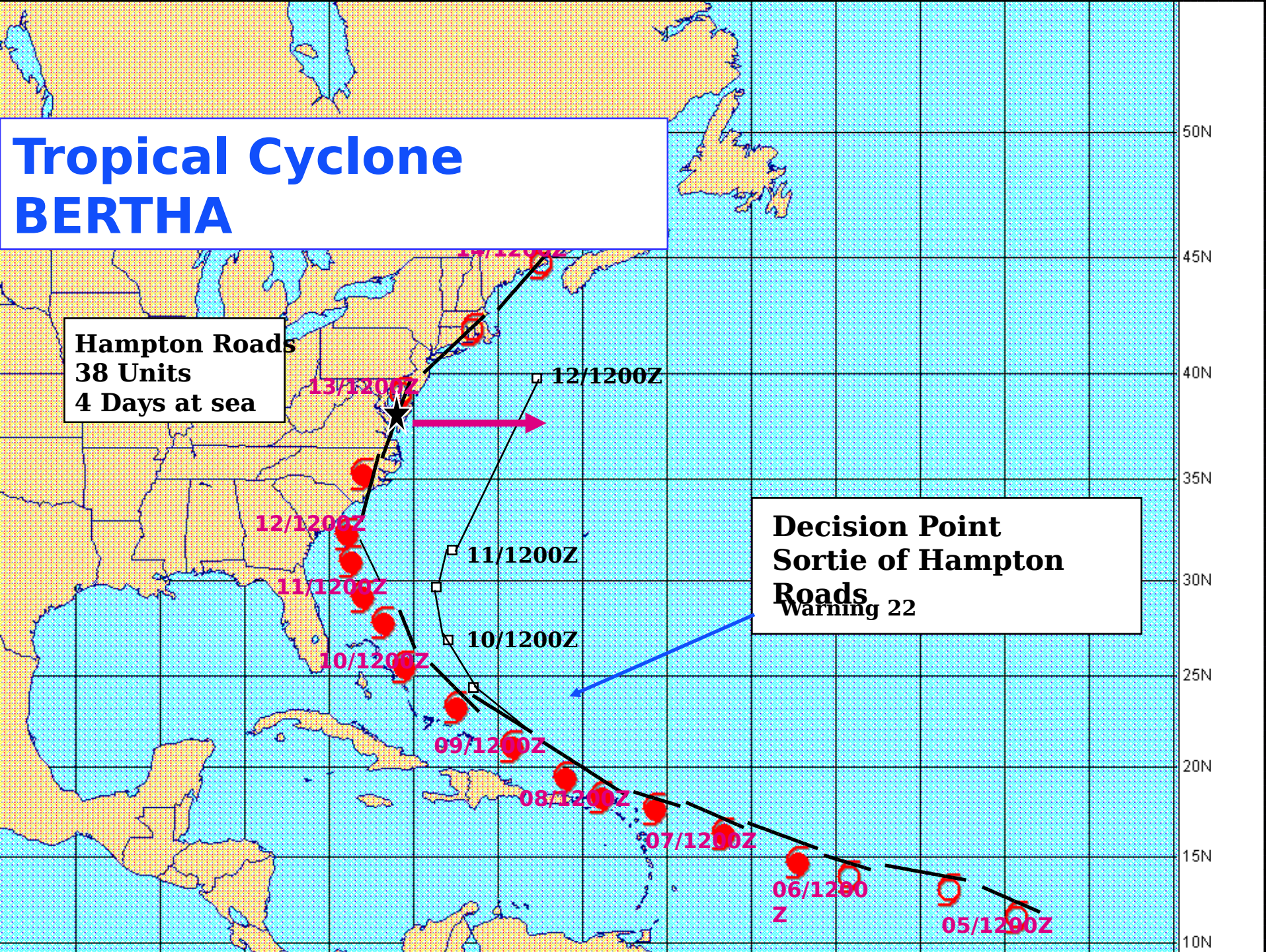
GOES-8 Color Enhanced IR
July 9, 1996 0915 GMT

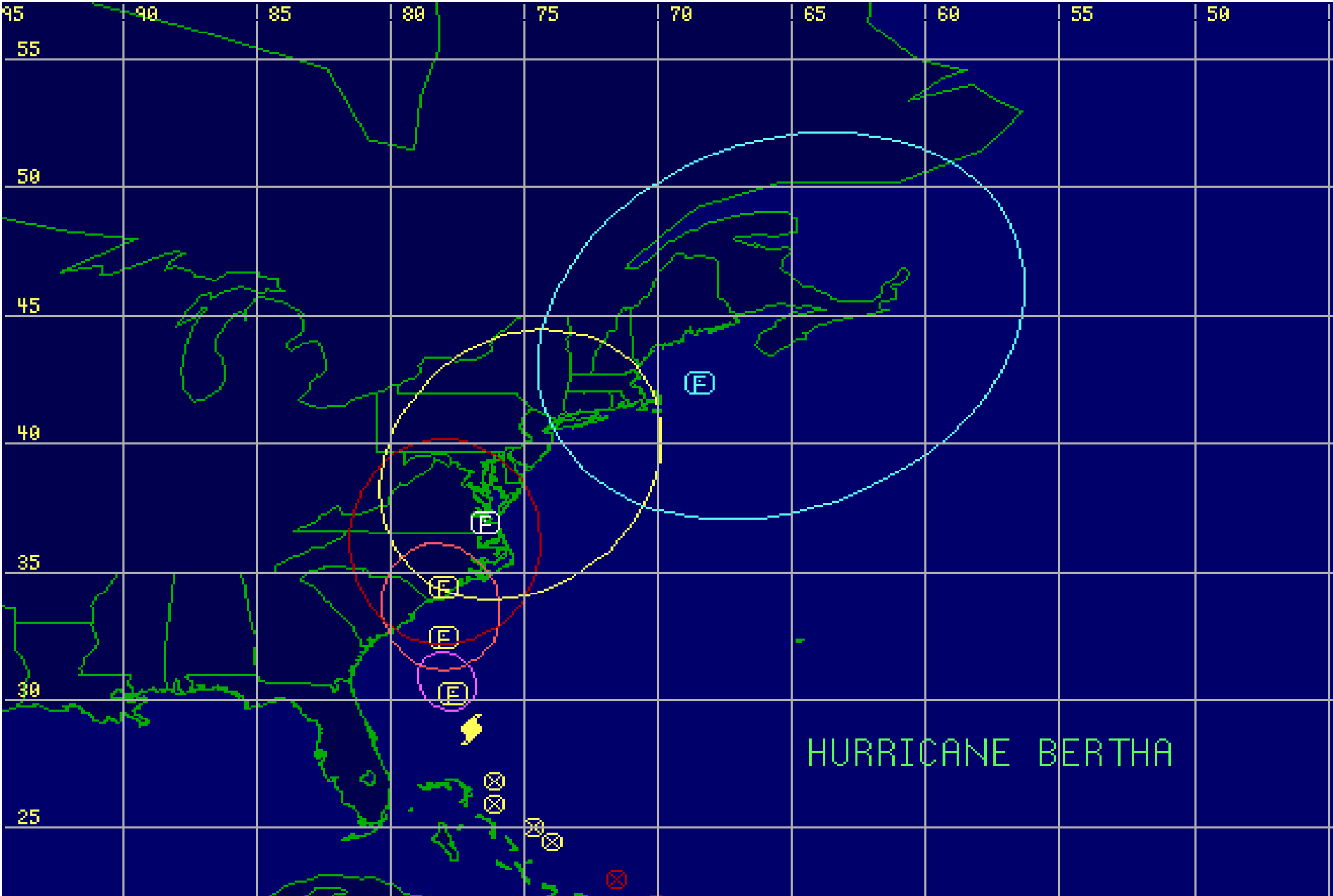


Tropical Cyclone BERTHA

Hampton Roads
38 Units
4 Days at sea

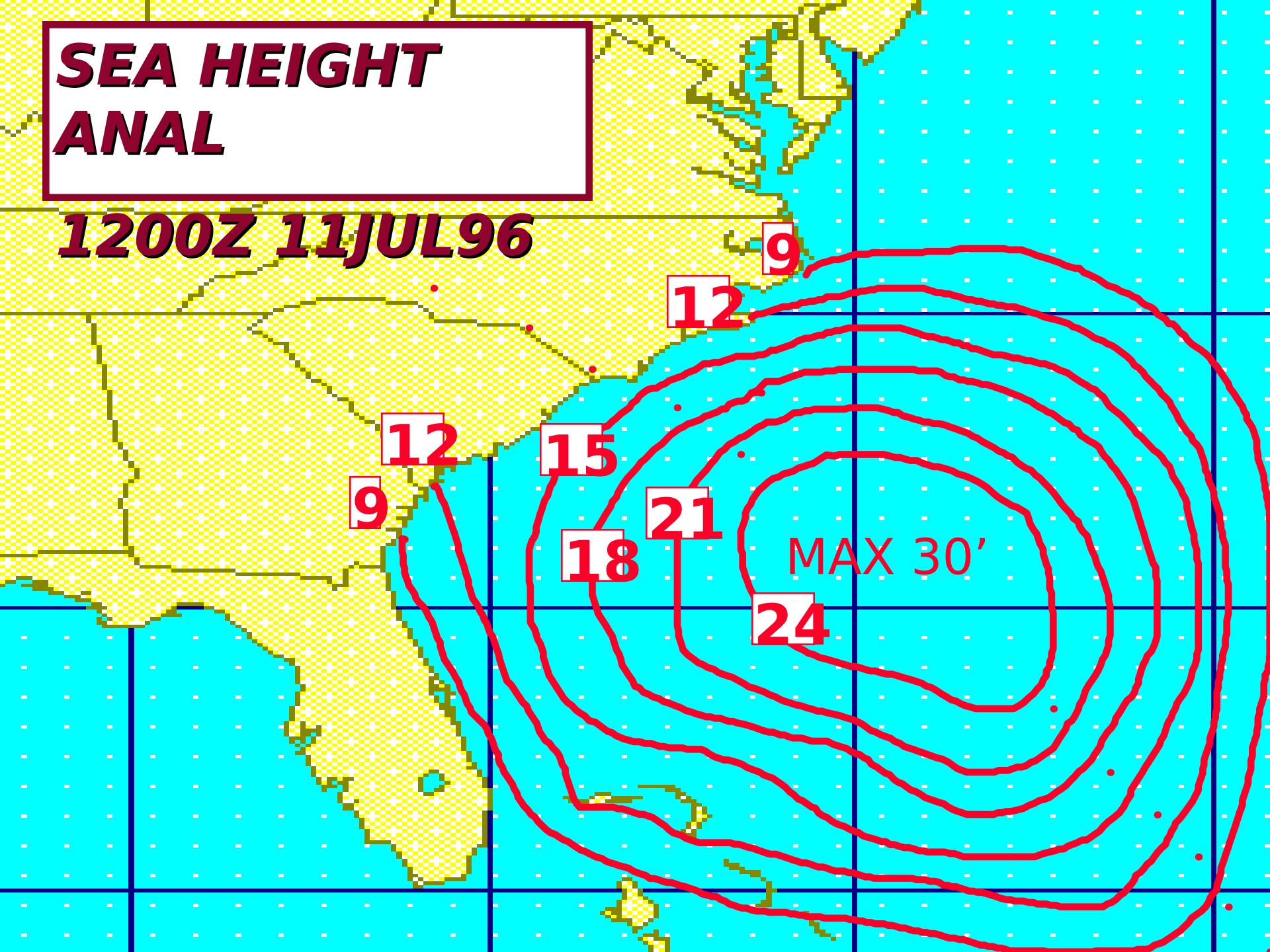
Decision Point
Sortie of Hampton
Roads
Warning 22





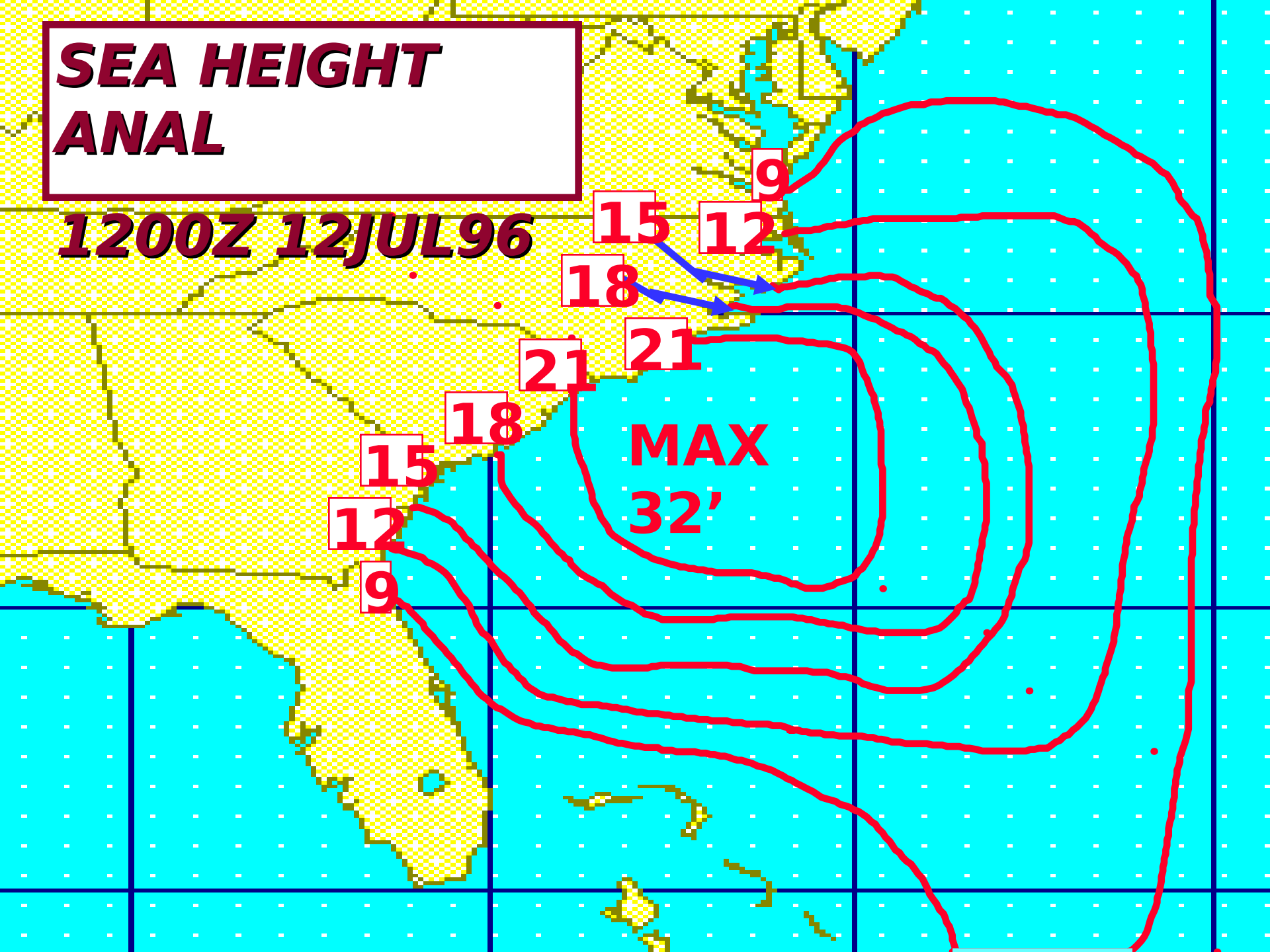
SEA HEIGHT ANAL

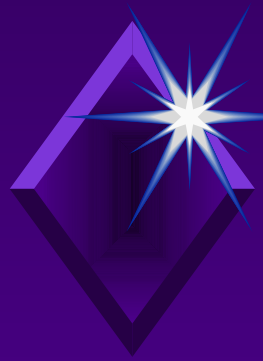
1200Z 11JUL96



SEA HEIGHT ANAL

1200Z 12JUL96





TROPICAL CYCLONE DISSIPATION

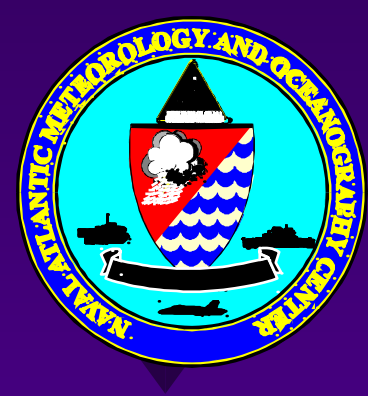
A. Recurvature:

- ◆ storms curve back east, usually accelerate, decrease in strength, but increase in diameter.

B. Frictional Forces of Land

C. Unfavorable atmospheric/oceanographic Influences:

- ◆ shearing, other Tropicals, etc...
- ◆ upwelling in wake



OTSR INFORMATION

A. Location: Bldg U-117, Norfolk Naval Air Station, Norfolk, VA

B. Hours: 24 hours per day, 7 days per week

C. Phone Numbers:

- ◆ Commercial: 757 444-4044 (DSN 564)
- ◆ STU: 757 445-4305 (DSN 565)

D. E-MAIL Address: OTSR@nlnmoc.navy.mil

E. Ship Routers:

- ◆ 2 civilian
- ◆ 2 military

1998 ATLANTIC TROPICAL CYCLONE NAMES

<i>ALEX</i>	<i>BONNIE</i>	<i>CHARLEY</i>
<i>DANIELLE</i>	<i>EARL</i>	<i>FRANCES</i>
<i>GEORGES</i>	<i>HERMINE</i>	<i>IVAN</i>
<i>JEANNE</i>	<i>KARL</i>	<i>LISA</i>
<i>MITCH</i>	<i>NICOLE</i>	<i>OTTO</i>
<i>PAULA</i>	<i>RICHARD</i>	<i>SHARY</i>
<i>TOMAS</i>	<i>VIRGINIE</i>	<i>WALTER</i>

**HURRICANE TRACKING CHART AVAILABLE:
www.nhc.noaa.gov/pasthur.html**